

The University of Chicago

FACTORS INFLUENCING THE QUALITY
OF HOME-CANNED MONTMORENCY
CHERRIES AND OF COOKED
JONATHAN APPLES

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF HOME ECONOMICS
AND HOUSEHOLD ADMINISTRATION
1944

By
RUTH M. GRISWOLD

Reprints of
MICHIGAN AGRICULTURAL EXPERIMENT STATION TECHNICAL BULLETINS
194 and 195, June, 1944

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By RUTH M. GRISWOLD

MICHIGAN STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION

SECTION OF FOODS AND NUTRITION

East Lansing

CONTENTS

	PAGE
Introduction and Review of Literature	3
General Experimental Procedure	4
Standard Canning Method	4
Objective Color Measurements and pH	5
Palatability Ratings	6
I. Variations in Method	6
Experimental Procedure	6
Discussion of Results	7
II. Variations in Ingredients	13
Experimental Procedure	13
Discussion of Results	14
III. Effect of Storage	20
Experimental Procedure	20
Discussion of Results	21
IV. Distribution of the Red Pigment in Raw and Canned Cherries	31
Experimental Procedure	31
Discussion of Results	32
Summary	33
Recommended Method for Canning Montmorency Cherries in Glass Jars	36
References	37
Acknowledgment	38

FACTORS INFLUENCING THE QUALITY OF HOME-CANNED MONTMORENCY CHERRIES

IN MICHIGAN AND IN OTHER FRUIT-GROWING STATES, LARGE QUANTITIES of sour red cherries are canned by home and commercial canners. There is a widespread belief that the quality of the canned cherries, and of other red fruits which are packed in smaller quantities, could be improved. One of the principal objections to the canned fruit is the faded color that often develops, but undesirable flavor changes are also a problem. Deterioration of palatability and of color seem to occur gradually during storage.

The color changes of canned cherries must be considered in relation to the pigments of the fruit. As in most red fruits, the principal pigment of cherries is an anthocyanin. That occurring in the skins of *Prunus avium*, a small black cherry, was studied first by Willstätter and Zollinger (1916), and later identified by Robinson and Robinson (1931) as cyanidin 3-monoside. The anthocyanins are water-soluble and amphoteric, usually forming red salts with acids, and blue, greenish blue, or violet metallic salts with bases (Gilman, 1943). These color changes depend on the nature of the anthocyanin and have been described for several purified anthocyanins dissolved in buffer solutions of varying pH by Robertson and Robinson (1929).

Color changes occurring in canned red fruits were studied by Culpepper and Caldwell (1927), who explained these changes on the basis of the color reactions of the anthocyanin pigments. They studied the effect of several metallic salts on aqueous extracts of cherries and on crude or partially purified pigments. They also canned cherries in glass jars and in enameled and plain tin cans. The appearance of some degree of alteration toward purple when the material was brought in contact with tin seemed to be a general and characteristic reaction of the anthocyanin pigments, occurring in both aqueous extracts and canned cherries. Prolonged storage in plain tin caused bleaching of the red color. The color changes of extracts of sour cherries were found to be similar but less intense than those of sweet cherries. Addition of acid to fruits that were highly pigmented and at the same time highly acid, depressed the formation of metallic salts of the pigment, and thus decreased the rate and extent of the solution of metal.

Methods used for the commercial canning of cherries have been described by Reynolds and Reynolds (1928). Stanley, Stienbarger and

CONTENTS

	PAGE
Introduction and Review of Literature	3
General Experimental Procedure	4
Standard Canning Method	4
Objective Color Measurements and pH	5
Palatability Ratings	6
I. Variations in Method	6
Experimental Procedure	6
Discussion of Results	7
II. Variations in Ingredients	13
Experimental Procedure	13
Discussion of Results	14
III. Effect of Storage	20
Experimental Procedure	20
Discussion of Results	21
IV. Distribution of the Red Pigment in Raw and Canned Cherries	31
Experimental Procedure	31
Discussion of Results	32
Summary	33
Recommended Method for Canning Montmorency Cherries in Glass Jars	36
References	37
Acknowledgment	38

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Methods used for the commercial canning of cherries have been described by Reynolds and Reynolds (1928). Stanley, Stienbarger and

Shank (1941) give household methods for canning cherries and other foods.

The study reported here was undertaken to determine the effect of variations in canning methods on the color and palatability of Montmorency cherries. Special attention has been given to variations that might be expected to affect the color of the fruit. While many of the variations tested are practical for household canning, some are borrowed from commercial methods, and some are largely of theoretical interest. For convenience, the experiments are grouped under the headings; (I) variations in method, (II) variations in ingredients, (III) the effect of storage, and (IV) the distribution of the red pigment in raw and canned cherries. In the first two sections, the canned fruit was stored for 9 or 10 months before examination, while in the third section, the changes in quality of cherries canned in various ways were followed periodically for 17 months. In the fourth section, an attempt was made to locate histologically the red pigment in raw and in canned cherries.

GENERAL EXPERIMENTAL PROCEDURE

Every group of canning experiments includes several series, each of which is to be considered as a unit for purposes of comparison, and is tabulated separately. Each series was canned from a mixed sample of cherries, and includes fruit canned by the standard method.

In the first part of this bulletin, the methods common to all the canning experiments will be described, and the standard canning method will be given. Variations from the standard method will be described later. In describing variations, it will be understood that the process was like the standard in all details except for the changes mentioned.

Montmorency cherries from the College Orchard were used. Since it was not possible to can all the cherries the day they were picked, three replicates were canned for each experiment from cherries picked the same day as canned and three from cherries picked on the previous day and held in a refrigerator. By equalizing the number of replicates in this way, it was believed that if a difference were found between the fresh and stored cherries it would not affect the results. The total number of jars canned for the first two sections of this report was 390, since 6 replicates were run for each of 65 variations. For the storage experiments in the third section, 404 jars were canned. The canning was done in the summer of 1941 except for a few tests in 1942.

STANDARD CANNING METHOD

As soon as the cherries were received, they were mixed in a large container. Portions were removed as needed, washed thoroughly, and

pitted with a household pitter. Half-pint glass jars and glass covers were prepared by heating in a steamer for at least 20 minutes. The jars were of the "lightning" type, the top being held in place with a wire clamp. Jar rubbers were dipped in boiling water just before use. One hundred and sixty-five grams of pitted cherries were weighed into the jar, and boiling sirup was then poured on the fruit to a level one-fourth inch from the top of the sides of the jar. The sirup was prepared with distilled water and 50-percent beet sugar by weight.

After the boiling sirup was poured over the cherries and the rubber rings were put in place, the jars were partially sealed and immersed at once in a large container of boiling water. The water extended one or two inches above the tops of the jars. The processing period was 25 minutes, the time recommended by Stanley, Stienbarger and Shank. (1941). The jars were removed from the water bath and the seal completed. When cool, the jars were put in covered boxes and stored at room temperature. All cherries were allowed to stand in covered boxes at room temperature for nine to ten months before examination.

OBJECTIVE COLOR MEASUREMENTS AND pH

Color of the canned cherries was determined objectively by the Munsell color system as described by Nickerson (1929). Since the cherries on the top of the jars had a slightly different color than those below, the top layer of fruit was removed before the remaining cherries were mixed. A sample of drained fruit was packed tightly into a cylindrical glass container having an internal diameter of 4.8 cm., a height of 2.8 cm., and a glass base. Because drying of the surface during a reading caused a change of color, the fruit was moistened with sirup several times during the color measurement. Two investigators made independent observations of the color of the fruit in each jar.

Color of the fruit was matched by four Munsell disks overlapped by means of radial slits and whirled by a motor fast enough to mix the color. The resulting color was matched in a color comparator eye-piece with that of the sample. Both sample and disks were illuminated by a Macbeth daylight lamp. In the Munsell system, color is described by means of its three attributes: hue, brilliance and chroma. *Hue is the name of a color and is designated by a number.* For instance, the hue number of red is 5, that of yellow-red 15, and that of red-purple 95. *Brilliance, also called value, is the lightness or darkness of a color.* Brilliance numbers go from one, which is black, to ten, which is white. *Chroma is the strength or purity of a color.* Its units begin with neutral gray, which is zero, and increase to 6 or even 14, depending on the maximum chroma possible with each color. In this system, any color can be designated by three numbers which are written in the sequence; hue, brilliance, chroma. Hue may be designated by either a word or a number. It is followed by

numbers indicating the brilliance and chroma of the disks. For determining the color of canned cherries, the disks were neutral 1/, neutral 5/, red 4/14 and yellow-red 6/12. The area of each of the disks was determined by means of a scale, and the hue and chroma of the sample were found in a table (Nickerson, 1935). The brilliance of some of the samples was calculated by means of a formula given by Nickerson (1929). Not many of the samples were calculated in this way because the work was time-consuming. The meaning of the terms used in the Munsell system is illustrated by the color insert between pages 6 and 7, which shows the color of canned cherries of poor and of good quality. Color readings were made on the canned fruit and the hue, brilliance and chroma of the samples were calculated.

The acidity of the fruit, as measured by hydrogen-ion concentration, was determined in some of the experiments by testing the juice with a Beckman glass-electrode pH meter. Preliminary experiments showed that the pH of the juice and of fruit ground in a mortar were the same.

PALATABILITY RATINGS

The palatability of the cherries was rated by a panel of four experienced judges, using score sheets. In these sheets, the factors color, appearance, texture of flesh, texture of skin, flavor of fruit and flavor of juice were graded on a scale of seven points. A grade of 1 signified that the sample was very undesirable in that factor, and a grade of 7 indicated that the sample was very desirable. Appropriate adjectives described the desirability of the intermediate grades. The judges gave their estimate of the general acceptability of the fruit by means of a series of seven adjectives ranging from very poor with a grade of 1 to excellent with a grade of 7. They were permitted to indicate a score half way between two grades when they wished.

Composite samples were prepared from triplicate cans for the judges. In this way the judges sampled two composites for each experiment, one from cherries canned the day picked and one from those canned the day after picking. Code numbers were used to prevent judges from learning the identity of the samples.

I. VARIATIONS IN METHOD

To determine the effects of variations in method, changes were made in the treatment of the fruit before canning, the processing time, the head space, and the processing method:

EXPERIMENTAL PROCEDURE

Since cherries frequently must be held before canning, a series was canned in which the holding period was the variable. Cherries were



Canned cherries of poor color compared with those of good color.

*(Hue, brilliance, and chroma are 11.7, 3.1, 3.2 for cherries of poor color;
6.0, 2.9, 4.1 for those of good color.)*

canned by the standard method immediately after picking, after 4 days in a refrigerator at 41° F. (5° C.), and after holding at room temperature 84° F. (29° C.) for 24 hours to simulate severe shipping conditions.

In commercial practice, cherries are soaked several hours in cold water to render them sufficiently firm to hold their shape and to pit easily. About six hours soaking at 55° F. (12.8° C.) or less is often used. An experiment was performed in which tap water was run continuously into the bottom of a container of cherries for 24 hours. The temperature of the water was about 61° F. (16° C.). Cherries were removed from the container for canning by the standard method after 0, 3, 7, 19, and 24 hours of this treatment.

Processing times of 10, 15, 20, 30, 35, and 45 minutes were compared with the standard time of 25 minutes.

The amount of oxygen left in the glass jars was increased by leaving ½-inch and 1¼-inch head space instead of the standard space of ¼-inch.

Several other methods of canning were compared with the standard cold-pack method. Jars were processed by putting them in the pressure cooker, bringing the pressure to 7½ pounds, and removing from the heat immediately. This treatment resulted in approximately the same temperature in the interior of the cans as the standard method. The hot-pack method was used in two ways. Sugar was added to the cherries in one test and 50-percent sirup in another, using the same proportion of cherries to sugar or sirup as in the standard method. In each case the fruit was boiled 5 minutes with the sugar or sirup, put in jars, and processed 5 minutes. The data in this series are given in full, as an example of the variations obtained in objective color data and in judges' scores. The standard errors of the means are included, and the significance of the differences between the corresponding means of the standard and the experimental packs was determined by Student's *t* test (Fisher, 1936). This was done not only to test the means in this series, but also to give an idea of what differences may be expected to be significant.

The effect of a larger proportion of sirup was tested by using half the standard amount of cherries, and filling the jar with sirup. An anti-browning agent in the form of Frulite* (thiocarbamide with starch) was used to test its effect on color. One 0.5-gram tablet of this agent was dissolved in a quart of water, the pitted cherries were put in the solution for 30 seconds, drained, and canned by the standard method.

DISCUSSION OF RESULTS

The experiment on holding the cherries before canning (Table 1) emphasizes the desirability of using freshly picked fruit. The hue of

*Obtained from the Boyce Thompson Research Foundation Incorporated, Yonkers, N. Y.

TABLE 1—Objective color data and judges' scores for cherries canned by various methods

Variation	Objective color†		Judges' scores**							
			Desirability of color	Appearance	Texture		Flavor		General acceptability	
	Hue††	Chroma*			Flesh	Skin	Fruit	Juice		
Holding period:										
None.....	7.5	4.2	5.1	4.8	5.1	4.9	5.1	5.6	5.2	
4 days at 5° C.....	7.8	3.8	4.5	5.0	4.9	4.7	4.8	5.1	4.2	
24 hours at 29° C.....	7.9	3.8	5.0	5.2	5.2	4.4	4.6	5.0	4.2	
Soaking in water:										
0 hours.....	7.5	4.2	5.1	4.8	5.1	4.9	5.1	5.6	5.2	
3 hours.....	7.8	4.0	5.5	5.2	5.8	5.2	5.9	5.9	5.8	
7 hours.....	7.9	4.1	5.2	5.0	5.5	5.5	5.4	5.8	5.1	
19 hours.....	8.2	3.8	4.9	5.2	5.1	4.8	5.1	5.0	4.7	
24 hours.....	8.2	3.8	4.9	4.9	4.6	4.2	4.6	5.1	4.4	
Processing times:										
10 minutes.....	8.0	4.0	4.1	4.2	5.4	4.6	5.1	5.4	4.6	
15 minutes.....	7.7	3.7	4.4	4.6	5.4	4.6	5.4	5.5	5.1	
20 minutes.....	7.7	4.0	4.6	4.6	5.4	4.9	5.4	4.6	5.1	
25 minutes.....	7.7	4.2	4.8	5.0	5.0	5.2	5.6	5.4	4.2	
30 minutes.....	7.6	4.2	4.7	4.8	4.9	5.4	5.1	5.2	4.6	
35 minutes.....	7.3	4.0	5.6	5.5	5.2	5.4	5.4	5.5	5.0	
45 minutes.....	7.5	3.8	5.0	4.9	4.5	5.1	5.1	5.3	4.6	
Head space:										
1/4 inch.....	7.1	4.1	5.8	5.6	4.9	5.2	5.4	5.5	5.1	
1/2 inch.....	7.5	3.9	5.2	5.2	5.0	5.4	5.4	5.6	5.0	
1 1/4 inch.....	7.8	3.7	4.6	4.7	4.8	4.8	4.6	5.2	4.4	
Miscellaneous:										
Standard.....	7.1	4.1	5.8	5.6	4.9	5.2	5.4	5.5	5.1	
Pressure cooker.....	7.6	4.1	4.9	4.9	4.6	4.8	4.5	4.6	4.1	
Hot-pack—sugar.....	7.5	3.8	4.6	2.2	2.8	3.2	4.2	4.1	2.5	
Hot-pack—syrup.....	8.3	3.8	4.2	2.9	2.9	3.5	4.1	4.2	2.8	
Extra sirup.....	8.4	3.9	4.6	4.4	4.9	4.5	4.3	3.9	3.6	
Fruitie.....	7.2	4.4	5.4	5.4	4.9	4.9	4.5	5.1	4.4	

†Each number is the average of twelve figures, as two investigators observed the color of six replicate jars.

††The hue number of red is 5; that of yellow-red 15.

*Chroma is the strength or purity of a color, neutral gray being zero, while higher numbers represent stronger colors.

**Scores are on the basis of seven as the most desirable, and one the least desirable grade. Each number is the average of eight figures, as four judges tasted two composites for each experiment.

fruit canned immediately was reddest (lowest hue number), becoming more orange (higher) for fruit held four days at 41° F. (5° C.) and at 84° F. (29° C.). Chroma was lower, indicating a less intense color, for fruit that was held. Cherries canned immediately were rated higher in texture of skin, flavor of fruit and juice, and general acceptability than fruit held at 5° C., and cherries held at 5° C. were as good or better in these factors than fruit held at 29° C. Less consistent differences were noticed in the other palatability factors. Perhaps the results can be explained by the fact that cherries held for 4 days at 5° C. were in better condition when canned than those held at 29° C. for 24 hours. Soaking in cold water at about 61° F. (16° C.) caused the color of the canned cherries to become more orange (increased hue) as the time of soaking increased from zero to 24 hours. Chroma decreased somewhat, although the change was less consistent than the change in hue. Cherries soaked for 3 hours before canning were more palatable than those canned without soaking. This may have been due to the greater firmness of the fruit when it was pitted. Reynolds and Reynolds (1928) say that after cherries are chilled and firmed for 4 to 5 hours in flowing cold water, they are firm, pit cleanly and hold their shape well in canning.

Soaking for 7 hours made the fruit less desirable than soaking for 3 hours in all factors except texture of skin. Soaking for 24 hours made the fruit less desirable in most palatability factors, especially texture, than no soaking. Peterson (1938) found that soaking Montmorency cherries for 6 hours at 50-55° F. (10-12.8° C.) had no injurious effects, and that firm cherries could be soaked 12 hours. According to this author, longer soaking caused losses in acids and solids, while soaking for more than 24 hours caused darkening of the skin and marked impairment of flavor.

Variations in processing time from 10 to 45 minutes for cherries in half-pint jars had only a slight effect on color, as measured objectively. The hue was somewhat more orange (higher) for underprocessed, and a little redder (lower) for overprocessed fruit. Variations in chroma were less consistent, and the chroma for cherries heated 10 minutes was about the same as for those heated 45 minutes. Differences in the palatability of cherries processed for various periods were not so great as might have been expected. Desirability of color, appearance and texture of skin increased rather consistently with processing time up to 35 minutes and then decreased, while scores for flavor of fruit increased up to 25 minutes. The texture of the flesh of cherries processed for the three shortest periods was preferred to that of fruit processed for the longer periods, owing to the softness of the overprocessed fruit. Changes in the flavor of the juice and general acceptability of the fruit

were less consistent, with scores for the overprocessed cherries not much different from those for underprocessed fruit.

The scores show that fruit processed for only 10 minutes was acceptable to the judges even after months of storage. However, such a short processing time could not be recommended because it would probably result in some spoiled fruit and certainly does not allow a margin of safety. Cherries processed 45 minutes were not far below those processed 25 minutes in most palatability factors, and received slightly higher scores for some items.

Increasing the head space from $\frac{1}{4}$ to $1\frac{1}{4}$ inches caused a consistent increase in the hue of the canned fruit, and a similar decrease in chroma, indicating that the color became more orange and less intense. Scores for desirability of color, appearance, and general acceptability were lower as more head space was present. Texture of the skin and flavor of the fruit and juice were less desirable for fruit with the largest amount of head space. All these changes are to be expected from the oxygen present in a jar that is only partially filled. This oxygen is believed to cause undesirable changes in the color and flavor of fruit, and should be excluded by leaving as little head space as is practical in canning. The best level to which the jars should be filled will, of course, vary with the type of jar used. It will be recalled that Ideal glass jars were used in canning the cherries and that the glass tops of these jars are curved upward in such a way as to leave head space additional to that measured from the top of the sides of the jar. For the most desirable head space, jars having flat tops, or tops that curved down, would be filled to a lower level.

Detailed objective color data and individual judges' scores for cherries canned by the standard method, the hot-pack method, and in the pressure cooker are given in tables 2 and 3. It will be seen that the standard errors of the means of the palatability scores are ± 0.2 to ± 0.5 , while those for the objective color data are ± 0.1 in every case. More variation would be expected in the judges' scores because of the unreliability of subjective judgments and because not all the data were accumulated at the same time. It is gratifying to find that the objective color data had such low standard errors. Evidently the method used was sufficiently accurate for the purpose. Both the standard errors and the results of the Student's *t* test (Fisher, 1936) indicate that for significance, differences must be greater between means of palatability data than between means of objective color data.

All the palatability factors for cherries canned in the pressure cooker were below those for the standard pack, but were not significantly different except for appearance. The hue for pressure-cooked cherries was significantly more yellow than for the standard, but the chromas

TABLE 2—Detailed objective color data for cherries canned by the standard method, the hot-pack method and in the pressure cooker†

Variation	Replicate	Hue		Chroma	
		Observer A	Observer B	Observer A	Observer B
Standard	1	7.0	6.9	4.3	4.0
	2	6.9	7.4	4.4	4.6
	3	6.5	7.0	4.8	4.1
	4	7.7	6.7	4.3	4.0
	5	7.2	7.1	3.5	4.2
	6	7.5	7.7	3.5	4.1
Average		7.1 ± 0.1		4.2 ± 0.1	
Pressure cooker	1	6.8	7.4	4.0	4.2
	2	7.2	7.2	4.0	3.9
	3	7.4	7.1	4.1	4.0
	4	8.4	7.6	4.2	3.9
	5	7.8	7.9	4.2	4.5
	6	8.0	7.8	4.3	4.4
Average		7.6* ± 0.1		4.1 ± 0.1	
Hot-pack with sugar ...	1	7.4	7.3	3.4	4.1
	2	7.4	7.1	3.6	4.1
	3	7.0	7.8	3.6	3.6
	4	7.8	7.3	3.5	3.9
	5	7.7	7.3	3.5	4.2
	6	7.8	7.7	3.9	3.9
Average		7.5* ± 0.1		3.8* ± 0.1	
Hot-pack with sirup ...	1	8.4	7.6	3.9	4.2
	2	8.2	7.6	3.5	4.5
	3	8.2	8.0	3.3	3.9
	4	8.7	8.7	3.7	3.7
	5	8.9	8.3	3.2	3.5
	6	8.5	8.3	3.8	4.3
Average		8.3** ± 0.1		3.8* ± 0.1	

†Each average is given with the standard error of the mean.

*Difference from corresponding mean of the standard is significant ($P = 0.05$).**Difference from corresponding mean of the standard is highly significant ($P = 0.01$).

were about the same. This method is not generally recommended for canning fruit, because of the equipment involved and the danger of overprocessing. The hot-pack methods, using either sugar or sirup, were not so successful as the standard (cold-pack) method. The differences between means for the standard and each of the hot-pack methods were significant or highly significant in every case, the scores for appearance, texture and general acceptability being particularly low. The color for both hot-pack methods was significantly more orange (higher hue) and less intense than for the standard pack.

Data for cherries canned with extra sirup and with Frulite (Table 1) belong in the series discussed above, but were not analyzed statistically. When extra sirup was present, because of using half the standard amount of cherries, the scores were lower than for the standard pack. The use of Frulite, an anti-browning agent, did not improve the quality of the

TABLE 3—Detailed judges' scores for cherries canned by the standard method, the hot-pack method, and in the pressure cooker†

Variation	Composite††	Judge	Desirability of color	Appearance	Texture		Flavor		General acceptability
					Flesh	Skin	Fruit	Juice	
Standard	A	1	6	6	5	5	5	5	4.5
		2	7	6	4	4	6	6	6
		3	5	5	4	5	5	5	4
		4	3	5	5	5	4	4	4
	B	1	6	6	6	6	6	6	5
		2	6	6	6	6	6	6	6
		3	6	6	5	5	5	5	5
		4	6	6	5	5	6	6	6
Average			5.8 ± 0.2	5.6 ± 0.2	4.9 ± 0.2	5.2 ± 0.2	5.4 ± 0.3	5.5 ± 0.3	5.1 ± 0.3
Pressure cooker	A	1	5	5	6	6	5	5	5
		2	6	5	4	4	4	5	4
		3	5	6	4	3	5	4	3
		4	6	6	6	6	5	6	5
	B	1	4	4	4	5	5	5	4
		2	5	5	5	5	5	5	5
		3	3	4	3	3	2	2	2
		4	5	5	5	5	5	5	5
Average			4.9 ± 0.4	4.9* ± 0.2	4.6 ± 0.4	4.8 ± 0.4	4.5 ± 0.4	4.6 ± 0.4	4.1 ± 0.4
Hot-pack with sugar	A	1	5	3	2	4	5	5	2
		2	6	2	2	5	6	5	2
		3	4	1	3	2	4	3	2
		4	5	3	4	3	2	2	2
	B	1	4	3	3	4	4	4	3
		2	6	2	2	3	5	5	3
		3	5	2.5	3	3	5	5	3
		4	2	2	3	2	3	4	3
Average			4.6* ± 0.5	2.2** ± 0.2	2.8** ± 0.2	3.2** ± 0.4	4.2* ± 0.5	4.1* ± 0.4	2.5** ± 0.2
Hot-pack with sirup	A	1	5	3	2	6	4	5	3
		2	6	2	2	4	5	3	2.5
		3	3	3	3.5	2	4	3	2.5
		4	5	3	4	3	5	4	4
	B	1	4	1	2	5	5	5	3
		2	4	1	2	3	4	3	3
		3	3	3	3	3	4	3	2
		4	4	3.5	3	2	4	3	2
Average			4.2** ± 0.4	2.9** ± 0.4	2.9** ± 0.3	3.5** ± 0.5	4.1* ± 0.4	4.2* ± 0.4	2.8** ± 0.2

†Each average is given with the standard error of the mean.

††Three replicate cans were mixed for each composite given to the judges. Composite A was of cherries picked the same day canned, while B was of cherries picked the previous day.

*Difference from corresponding mean of the standard is significant ($P = 0.05$).**Difference from corresponding mean of the standard is highly significant ($P = 0.01$).

fruit. Of course, browning is not so great a problem with red cherries as with such fruits as peaches and pears.

II. VARIATIONS IN INGREDIENTS

In this section the effects of variations in the composition of the water, the amount and kind of acid present, the quantity of sugar added and the degree of ripeness of the cherries were investigated.

EXPERIMENTAL PROCEDURE

Variations in the water used were studied in the water-pack series. Boiling water was poured over the fruit instead of sirup, and the processing period was 7 instead of 25 minutes because of the more rapid heat penetration in water-packed fruit. The standard in this series was distilled water. It was compared with tap water, and several of the constituents of tap water that might affect the color of cherries were added to distilled water in the amounts found in some tap waters. The proportions of chemicals added were on the basis of the water, not the entire pack. Ferrous sulfate equivalent to 0.05 part per million of iron was added. Sodium hydroxide was added to boiled distilled water until the alkalinity was equal to that of boiled college tap water, pH 8.7. The effects of iron and alkali were combined by adding to distilled water 0.05 part per million of iron as ferrous sulfate and sodium hydroxide to pH 8.7. Tin such as might be dissolved from a can was added in the form of 5 parts per million of stannous chloride, and a level of 1 part per million of iron as ferrous sulfate was also used. Because of its use in firming canned tomatoes, 0.4-percent calcium chloride was added to the water for one of the experiments. Cherry juice, prepared by boiling mashed cherries and allowing them to drip through a jelly bag, was used in place of water in another experiment. Since some of the variables tested in the water-pack series might be expected to have a different effect after air had free access to the fruit, observations were made within 3 hours and 24 hours after the jars were opened. The hues of the water-pack series were analyzed statistically by the analysis of variance in order to test the significance of differences between the means of the treatments and to test the magnitude of some of the sources of error common to all the experiments.

An acid series was canned to find out what effect hydrogen-ion concentration has on the color and quality of the fruit. Malic acid, the principal acid of cherries (Bigelow and Dunbar, 1917, and Nelson, 1928), was added so that its concentration in the sirup was 0.13 to 1 percent. The extra acid would simulate conditions in underripe fruit. Citric acid also is present in many fruits, and its effect was tested by adding to the sirup amounts that were equimolecular compared with malic

acid. These amounts ranged from 0.18 to 1.44 percent. The citric acid series was repeated in the summer of 1942 because of some difficulty in matching the color of the cherries canned in 1941. The 1942 data are reported for this series. Lemon juice was used (1941) in amounts calculated to furnish the same quantity of citric acid as was used in the citric acid experiments. These amounts were from 3.02 to 24 percent of the sirup.

In the sugar series, sirups containing from zero to 70-percent sugar were used. The processing time was 25 minutes for the entire series. The specific gravity of the juice in the cans after storage was determined by comparing the weight of a given volume of juice with the weight of the same volume of water, and the apparent sugar concentration in the juice was calculated from the specific gravity figures.

Since degree of ripeness might be expected to affect the color and palatability of canned cherries, underripe and overripe cherries were compared with fruit of standard ripeness. Unpitted cherries were also used.

DISCUSSION OF RESULTS

The data for the water-pack series are shown in Table 4, and a detailed statistical analysis of the hue of these cherries in Table 5. It will be seen from the analysis that the effects on hue of the treatments were not significantly different. Since the averages for distilled water and tap water are so close, the individual constituents of tap water, such as hydrogen-ion concentration and iron, would hardly be expected to affect the hue. The cherry juice appeared to make the fruit slightly redder (lower hue), and the tin or the higher concentration of iron appeared to make the fruit somewhat more orange than the standard distilled water, differences which were not statistically significant. Culpepper and Caldwell (1927) found that aqueous extracts of sour cherries showed slight to moderate purpling with stannous chloride or aluminum chloride, and some blackening with ferric chloride. The concentration of these salts was not mentioned but was probably higher and might have had more effect than those used in the present experiment.

As in all the other experiments, three of the replicates were prepared from fruit picked the same day, and the remaining three replicates from fruit picked the preceding day. The hue of fruit canned after storage overnight in a refrigerator was significantly higher (8.6) than that of fruit canned when freshly picked (8.3), as might be expected. In this series, the color of the fruit was determined immediately after opening the jar and 24 hours after the jar had been opened. The hue of the fruit examined immediately was significantly lower, 8.4, compared with 8.5 for fruit that had stood 24 hours after opening the jar. Since people see colors differently, it was not surprising to find that the two

TABLE 4—Objective color data, pH and judges' scores for cherries canned in the water-pack and acid series*

Objective color				Judges' scores				General acceptability			
Hue		Chroma		pH	Desirability of color	Appearance	Texture		Flavor		
3 hr.	24 hr.	3 hr.	24 hr.				Flesh		Skin	Fruit	Juice
Water-pack:											
Distilled water.....	8.2	8.5	3.9	3.7	3.5	5.2	4.9	3.4	3.2	2.9	
Tap water.....	8.4	8.4	3.8	3.7	3.6	4.8	4.8	3.0	3.4	3.1	
0.05 ppm Fe as Fe So ₄	8.3	8.5	4.1	3.6	3.6	4.9	4.6	3.2	3.0	2.8	
Na OH to pH 8.7.....	8.6	8.4	4.0	3.6	3.6	5.1	4.6	3.1	3.5	3.0	
0.05 ppm Fe as Fe So ₄ and Na OH to pH 8.7.....	8.6	8.7	4.0	3.3	3.6	4.6	4.5	3.0	3.2	2.9	
5 ppm Sn Cl ₂	8.5	8.5	4.3	3.6	3.6	4.8	4.0	2.5	3.2	2.5	
1 ppm Fe as Fe So ₄	8.5	8.7	3.9	3.4	3.6	4.6	4.0	2.8	2.8	2.6	
0.4% Ca Cl ₂	8.3	8.6	4.4	3.6	3.5	4.6	3.4	2.6	2.8	2.4	
Cherry juice.....	7.9	8.3	3.3	2.9	3.6	5.0	4.9	2.8	3.0	2.6	
Malic acid (1941):											
0%.....	7.7	.....	4.2	.....	3.5	5.0	5.2	5.6	5.4	4.2	
0.13%.....	7.7	.....	3.7	.....	3.5	5.4	5.2	5.2	5.2	4.8	
0.25%.....	7.7	.....	3.3	.....	3.5	4.0	3.9	5.0	4.4	4.6	
0.50%.....	7.6	.....	3.5	.....	3.4	5.1	4.9	4.8	4.2	4.4	
0.75%.....	7.7	.....	3.4	.....	3.4	4.4	5.4	4.6	4.8	4.2	
1.00%.....	7.7	.....	2.5	.....	3.3	4.9	5.4	4.9	4.8	4.4	
Citric acid (1942):											
0%.....	7.2	.....	5.5	.....	.....	4.1	4.8	4.5	4.8	4.0	
0.18%.....	7.3	.....	5.2	.....	3.3	4.0	5.0	4.4	4.4	3.8	
0.36%.....	7.2	.....	5.6	.....	3.3	3.9	4.6	4.1	4.5	3.5	
0.72%.....	7.0	.....	5.4	.....	3.2	3.5	4.9	3.9	4.1	3.2	
1.07%.....	6.8	.....	5.0	.....	3.1	3.1	4.6	3.2	4.0	3.1	
1.44%.....	6.9	.....	4.2	.....	3.1	3.2	4.0	3.4	3.5	2.9	
Lemon juice (1941):											
0%.....	7.7	.....	4.2	.....	3.5	5.0	5.2	5.6	5.4	4.2	
3.02%.....	7.4	.....	3.4	.....	3.5	4.6	4.8	4.9	4.9	4.1	
6.04%.....	7.9	.....	3.4	.....	3.5	4.2	4.9	4.5	4.9	4.1	
12.10%.....	.....	.....	.....	.....	3.4	4.1	4.2	3.5	3.8	2.9	
18.00%.....	7.7	.....	3.0	.....	3.4	4.2	4.8	3.4	3.9	3.1	
24.00%.....	8.7	.....	3.1	.....	3.3	4.0	4.7	2.6	2.8	2.2	

*Averages obtained as for Table 1.

TABLE 5—*Analysis of variance of the hue of cherries canned in the water-pack series*

Source of variance	Degrees of freedom	Variance
Total.....	215	
Treatments.....	8	0.5375
Storage (fresh and stored).....	1	4.6112**
Tr. x S.....	8	0.6463
(a) cans (within).....	36	0.4181
Time (immediately and after 24 hours).....	1	1.2911**
Tr. x Ti.....	8	0.1593
Ti. x S.....	1	0.3849
Tr. x Ti. x S.....	8	0.0810
(b) Ti. x C.....	36	0.1411
Investigators.....	1	7.7520**
Tr. x I.....	8	0.0603
I. x S.....	1	0.5381*
I. x Ti.....	1	0.0144
(c) { I. x C.....	36	0.1040
C. x Ti. x I.....	36	0.1046
Tr. x I. x Ti.....	8	0.1028
Tr. x I. x S.....	8	0.1534
Ti. x I. x S.....	1	0.0777
Tr. x I. x Ti. x S.....	8	0.2404

Use (a) error to test variances above (a)

Use (b) error to test variances above (b) and below (a)

Use (c) (either interaction) to test all other variances.

*Significant.

**Highly significant.

investigators who examined the fruit differed significantly in their judgments, obtaining average hues of 8.2 and 8.6. However, the analysis showed that the data for hue obtained by the two investigators could be averaged, since the interaction of investigators with treatment was not significant. Such an interaction indicates that the differences between the means for hue obtained by the two investigators were about the same for each experimental treatment and that an average of the data obtained by the two investigators would represent a valid mean. Similar reasoning applies to data for cherries canned immediately after picking and those stored overnight in a refrigerator.

The chroma of the water-pack series was not widely different, although that for the cherry-juice sample seems low. The pH values of the samples are very similar, as might be expected from the fact that the fruit contains natural buffers.

The judges' scores for the palatability of the water-pack cherries do not show striking differences. The fruit containing one part per million iron graded below that containing 0.05 p.p.m. on all points, and that containing both iron and sodium hydroxide was graded in most factors below the samples containing either the iron or the alkali. Stannous chloride seemed to lower scores for flavor of fruit and general acceptability, while calcium chloride made the texture of the skin, the flavor, and the general acceptability undesirable.

Since anthocyanins generally have a reddish color in acid solutions

and a bluish tint in alkali, it was thought that the addition of acid in canning might intensify the red color of the fruit. Additional acid would occur naturally in underripe fruit. The pH values (Table 4) indicate that the quantities of acid added were not sufficient to change greatly the hydrogen-ion concentration of the canned fruit. The pH varied from 3.5 for cherries containing no added acid, to 3.3 for those containing the largest amounts of malic acid and lemon juice, and 3.1 for fruit containing the highest level of citric acid.

The judges' scores indicate that the color of the fruit became less desirable as the quantity of each acid increased. However, the objective color data show that hue changed little as the amounts of malic and citric acids increased, but became more yellow with the largest amount of lemon juice. It is not surprising that lemon juice does not react like the pure acids, since it contains a variety of compounds, including pigments. The chroma decreased as the two acids and lemon juice increased, indicating that the color became weaker. This probably explains the decrease in the judges' scores for desirability of color. Cherries containing the largest amounts of acid looked dull, almost brownish.

Both subjective and objective scores for the color of cherries canned with citric acid were better than for those canned with malic acid or lemon juice. However, no importance can be attributed to this fact because this citric acid series was canned in 1942 while the other two series were canned in 1941. The 1941 palatability data for citric acid, which are complete, indicate no significant difference in the desirability of the color of the malic and citric acid series.

Scores for the general appearance of the cherries are not widely different for the three acids, but show a rather steady decrease as the quantity of the acid increases. Texture of the skin did not change so much with increasing amounts of acid as texture of the flesh, which became less desirable owing to excessive softness of the fruit containing the higher amounts of acid. The flavor of the fruit and juice became less desirable as the amounts of acid increased. The largest quantities of acid made the fruit quite sour. The judges' scores for general acceptability of the cherries were less favorable at the higher concentrations of citric acid and lemon juice. It is of interest that cherries to which malic acid had been added were scored slightly higher on general acceptability and on several other palatability items than fruit containing lemon juice and citric acid. Possibly this is because of the natural occurrence of relatively large quantities of malic acid in cherries.

In the sugar series (Table 6), the hue figures are somewhat inconsistent, but the chroma data indicate that the samples canned in sirups of higher sugar concentration had a less intense color than those in less

TABLE 6—Objective color data, judges' scores and sugar concentration calculated from specific gravity for cherries canned in various sirups and of different degrees of ripeness*

Variation	Objective color			Judges' scores							Sugar concentration from specific gravity
	Hue	Brilliance**	Chroma	Desirability of color	Appearance	Texture		Flavor		General acceptability	
						Flesh	Skin	Fruit	Juice		
Sirup concentration:	7.3	3.2	5.1	5.0	4.0	3.1	4.2	3.4	3.5	3.0	(percent) 10.0
	7.6	3.2	5.1	4.9	3.8	2.9	4.0	3.9	3.9	2.9	13.8
	7.3	3.0	4.8	5.1	4.4	3.6	4.8	4.5	4.5	3.9	17.2
	7.5	3.1	4.8	5.2	4.8	4.2	5.1	5.4	5.2	4.9	21.0
	40%	2.8	4.1	5.4	5.2	5.4	5.8	5.8	5.9	5.6	24.3
	45%	2.8	4.3	5.8	5.5	5.4	5.5	6.0	5.6	5.5	27.5
	50%	2.8	4.0	5.8	5.4	5.8	5.6	5.6	5.5	5.4	30.0
	55%	2.9	4.3	6.0	5.8	5.4	4.9	5.1	4.9	4.9	30.1
	60%	2.7	4.2	5.6	5.6	5.2	4.8	4.6	4.4	4.3	32.2
	70%	2.6	3.9	5.6	5.6	5.2	4.2	4.2	4.2	4.3	36.9
Condition of fruit:											
	Underripe		4.5	2.6	3.2	4.1	4.8	4.2	4.2	3.4	
	Standard		4.2	5.1	4.8	5.1	4.9	5.1	5.6	5.2	
	Overripe		3.7	5.2	5.6	4.9	4.9	4.8	5.4	4.6	
Unpitted	7.8		3.6	5.1	5.4	5.4	5.8	5.6	5.6	5.3	

*Averages obtained as in Table 1.

**Brilliance numbers go from one, which is black, to ten, which is white.

concentrated sirups.* Brilliance was calculated for this series, and it was found to decrease as the sugar concentration increased, indicating that fruit in the more concentrated sirups was darker than that in more dilute sirups. As might be expected, the desirability of the palatability factors increased at first with increasing sugar concentration and then declined. The judges preferred the color and appearance of cherries canned in 55-percent sirup, the texture of the flesh of those canned in 50-percent sirup, and the flavor of the fruit of those canned in 45-percent sirup, but rated those canned in 40-percent sirup best for texture of skin, flavor of juice and general acceptability. Evidently a 40- or 45-percent sirup would have been more generally acceptable than the standard 50-percent sirup.

The figures for the apparent sugar concentration of the juice, as calculated from its specific gravity, indicate the way in which the added sugar divides itself between the fruit and the juice. The estimate is rough, because of the effect on specific gravity of constituents of the juice other than sugar. When little or no sugar was added to the fruit, the juice from the stored jars apparently contained more sugar than the original sirup because of the passage of water-soluble substances from the cherry, where they were more concentrated, to the water or sirup where they were less concentrated. When more concentrated sirups were added, however, the apparent sugar concentration of the juice was lower than that of the original sirups, as would be expected from the laws of diffusion. According to Chatfield and Adams (1940), the sugar content of the flesh of sour cherries is 9.5 percent and their total carbohydrate content 13.3 percent.

It seemed desirable to compare the quality of underripe, overripe and unpitted cherries with those of standard ripeness (Table 6). The canned underripe cherries had a stronger and more yellowish color than the fruit of standard ripeness, as indicated by a higher hue and chroma, while the overripe cherries had a redder, less intense color. The judges liked the color and appearance of the overripe cherries but preferred the standard cherries to either the underripe or overripe fruit on all other points.

The color of the canned, unpitted cherries was slightly redder and less intense than that of the standard. The judges graded the unpitted fruit higher than the standard, pitted fruit in all factors except color desirability and flavor of juice for which the scores were identical. They liked the appearance and flavor of the unpitted fruit.

*One jar of cherries containing 10 percent sugar sirup was discarded because of mold on the rubber. This was the only spoilage observed in all the cherry canning experiments, except for the perforated enamel cans mentioned in the next section of the paper.

III. EFFECT OF STORAGE

To study the gradual loss of quality often observed in canned cherries, changes in the fruit were followed for 17 months. Cherries were canned in water and in sirups containing sucrose, dextrose, a mixture of those two sugars, and pineapple juice. Various containers and storage conditions also were studied. Several brands of cherries commercially canned without sugar were examined and compared with the experimental fruit. The effect of storage in a refrigerator on the color of cherries in a jar that had been opened was determined.

EXPERIMENTAL PROCEDURE

The standard canning method was the same as in the previous sections. As before, one-half the jars in each pack were filled with cherries picked the same day canned, and the other half with cherries picked the previous day and held overnight in a refrigerator. Except where otherwise noted, the jars were stored in covered boxes at room temperature, about 68° F. (20° C.).

Forty-four jars of each of the following variations were prepared in the summer of 1941.

1. *Water-pack.* Distilled water was used instead of sirup and the processing time was 7 minutes, owing to the more rapid penetration of heat in water than in sirup.

2. *Sirup containing 50-percent sugar (sucrose).* This is the standard for the entire series.

3. *Sirup containing 55-percent dextrose (corn sugar, cerelose*).* Because of the water content of dextrose, 55 percent is approximately equivalent to 50-percent dry sugar.

4. *Sirup containing 27-percent dextrose plus 25-percent sucrose.*

5. *Sirup containing 50-percent sucrose in half water, half pineapple juice.*

6. *Sirup containing 50-percent sucrose.* The jars were stored on a light but not sunny shelf at room temperature.

7. *Sirup containing 50-percent sucrose.* The jars were stored in the dark at 10° C. $\pm$ 2° C. (50° F.).

8. *Sirup containing 50-percent sucrose.* Enameled tin cans ($\frac{1}{2}$ No. 2 or No. 307 $\times$ 208 improved R enamel) were used instead of glass jars. Each can was filled with 190 gm. pitted cherries, boiling 50-percent sirup was poured to within $\frac{1}{2}$ inch of the top, the can was exhausted 10 minutes in boiling water, sealed, and processed 15 minutes in boiling water. Thus the total period of heating was the same as in the standard method, 25 minutes. A preliminary experiment showed no differ-

*Analysis of cerelose furnished by Corn Products Sales Company: dextrose, 91.0%; moisture, 8.5%; ash, 0.05%; purity, 99.5%.

ence between fruit canned by the standard method and by exhausting and then processing in the glass jar.

The fruit was examined, four jars at a time, at first frequently, and then at longer intervals, until 10 examinations had been made over a period of 17 months. Two of the four jars were from fruit canned the same day picked and two were from cherries picked the day before canning. Two observers measured objectively the color of the fruit in each jar by the Munsell system. The tasting was done on two, rather than four replicates.

For comparison with enameled tin, six samples were preserved in plain tin cans. The same sized can and the same canning method were used in each case. This fruit was examined after only one storage period of 11 months.

After comparing the effects of storage on water-packed and sirup-packed cherries, it seemed desirable to study the effect of adding sugar before and after canning especially in view of the sugar shortage at that time. During the summer of 1942, eight jars were canned by the standard method, using 50-percent sirup. Another eight jars were canned, using water instead of sirup, and processed for 7 instead of 25 minutes. After storage for 9 months, the water-packed jars were opened and to each jar was added the amount of sugar that would have been present if 50-percent sirup had been used instead of water. After standing 48 hours to allow the sugar to become evenly distributed, the 16 jars were examined.

An additional test of storage conditions was made in 1942. Twenty-four jars of cherries were canned by the standard method, using 50-percent sirup. Half of the jars were stored in the dark at room temperature and half on shelves where they were exposed to the light but not to the sun. All jars were examined after 9 months of storage.

The quality of six brands of commercially canned cherries was studied by palatability tests and objective color readings. All were packed without sugar, one in juice and the others in water. The approximate storage periods were found by mailing the end of the can containing the code numbers, to the manufacturers, who furnished the date of packing. To determine whether the quality of fruit changed after the jar was opened and held in the refrigerator, quart jars of cherries were canned. After 10 months of storage, the jars were opened and examined every few days for 19 days. The fruit was held in a refrigerator at 2° C. (35.6° F.) and remained in good condition.

DISCUSSION OF RESULTS

Objective color data, pH, and judges' scores for cherries examined in the eight storage experiments are shown in Table 7. All data in the storage series were plotted against time. Almost without exception,

TABLE 7—Objective color data, pH, and judges' scores for canned cherries stored for various periods

Variation and storage period	Objective color*		pH	Judges' scores**					General acceptability		
	Hue	Chroma		Desirability of color	Appearance	Texture		Flavor			
						Flesh	Skin	Fruit		Juice	
Raw cherries											
Water-pack:											
1 week...	5.3	3.8	3.3	5.2	5.4	4.6	4.0	4.0	4.1	3.8	3.8
2 weeks...	5.6	8.4	3.3	4.8	4.6	4.0	3.6	3.6	3.3	3.6	3.6
1 month...	6.2	7.8	3.4	4.8	4.3	4.4	3.7	3.5	3.5	3.5	3.5
2 months...	6.1	7.1	3.5	4.1	4.4	4.0	3.5	3.5	3.1	3.1	2.8
3 months...	6.6	6.6	3.5	4.1	4.6	4.4	3.4	2.9	2.9	2.9	2.7
5 months...	7.7	5.4	3.6	3.8	4.4	4.0	3.9	3.4	3.4	3.4	2.6
8 months...	8.0	4.3	3.0	3.3	4.4	3.9	3.5	3.4	3.4	3.4	2.0
11 months...	9.1	4.4	3.4	3.6	3.9	3.8	3.2	2.8	2.8	2.8	1.7
14 months...	9.4	4.4	2.2	2.3	1.8	2.5	1.8	1.8	1.8	1.8	1.7
17 months...	10.1	4.0	2.0	2.2	1.8	2.5	1.8	1.8	1.8	1.8	1.7
50% sucrose—stored in dark:											
1 week...	5.3	6.5	6.1	5.8	5.9	5.6	6.2	6.0	6.0	5.9	5.9
2 weeks...	5.5	5.6	5.8	5.8	5.6	5.4	5.0	5.0	5.2	5.2	5.7
1 month...	5.6	5.9	5.8	4.8	5.7	5.0	6.0	6.2	6.2	6.2	5.8
2 months...	6.0	5.4	5.5	5.5	5.8	5.5	5.5	5.5	5.5	5.5	5.5
3 months...	6.2	4.4	5.4	5.5	5.4	5.8	5.5	5.5	5.6	5.6	5.5
5 months...	6.5	4.9	5.7	5.5	5.6	5.4	5.7	5.5	5.4	5.4	5.3
8 months...	6.9	4.1	5.6	5.2	5.6	5.4	5.2	5.4	5.2	5.2	4.6
11 months...	7.8	4.1	5.1	5.2	4.2	4.8	5.2	5.2	5.2	5.2	4.2
14 months...	8.6	4.0	3.8	4.2	4.2	4.1	4.8	5.2	5.2	5.2	4.2
17 months...	9.1	3.0	3.5	4.2	4.2	4.2	4.2	4.8	5.2	5.2	3.9
55% dextrose:											
1 week...	5.3	6.1	5.8	5.6	5.2	4.6	4.6	4.8	5.0	4.8	4.8
2 weeks...	5.7	5.7	5.1	5.2	5.2	4.5	4.5	4.8	4.8	4.7	4.4
1 month...	5.7	5.7	5.2	4.8	5.2	4.8	4.6	4.5	4.5	4.4	4.6
2 months...	5.8	5.0	5.2	5.1	5.2	5.4	5.0	4.6	4.5	4.5	5.1
3 months...	6.4	4.3	5.2	5.4	5.4	4.6	4.6	4.0	4.0	4.0	4.0
5 months...	6.6	4.3	5.1	5.4	5.0	4.8	4.3	4.3	4.4	4.4	3.8
8 months...	6.6	3.7	5.1	4.5	4.8	4.0	3.5	4.4	4.4	4.4	3.8
11 months...	7.6	3.6	4.8	4.5	4.8	4.0	3.5	4.4	4.4	4.4	3.8
14 months...	8.1	3.6	4.1	4.1	4.8	4.1	3.3	4.4	4.4	4.4	3.8
17 months...	8.5	3.1	3.5	3.7	3.5	4.2	3.8	4.4	4.4	4.4	3.2
27% dextrose + 25% sucrose:											
1 week...	5.3	6.4	6.0	5.9	5.9	5.0	5.8	6.1	5.6	5.6	5.6
2 weeks...	5.4	5.4	5.5	5.2	5.7	5.2	5.1	5.3	5.5	5.3	5.3
1 month...	5.7	5.8	5.3	5.4	5.4	5.2	5.0	5.0	4.8	4.8	4.6
2 months...	6.0	5.1	5.6	5.3	5.4	5.3	5.0	4.6	4.5	4.5	4.6
3 months...	6.8	4.7	5.4	5.6	5.5	5.3	5.6	5.3	5.3	5.3	5.1
5 months...	6.8	4.1	5.4	5.5	5.3	5.3	5.6	5.6	5.3	5.3	4.8
8 months...	6.9	4.0	5.4	5.5	5.1	4.6	4.9	4.6	4.8	4.8	4.4
11 months...	7.7	3.7	5.0	4.8	4.8	4.4	4.6	4.6	4.5	4.5	4.4
14 months...	8.5	3.6	3.9	4.2	4.8	4.8	4.1	4.6	4.5	4.5	4.4
17 months...	8.7	3.0	3.7	4.2	4.7	4.7	4.3	4.6	4.4	4.4	3.9

50% sucrose in half pineapple juice:

1 week.....	5.4	6.4	3.3	5.6	5.5	5.2	6.1	5.8
2 weeks.....	5.5	5.5	3.5	5.9	5.8	5.5	6.0	5.5
1 month.....	5.6	5.5	3.5	5.8	5.5	5.5	6.0	5.6
2 months.....	6.0	5.2	3.5	5.0	5.1	5.5	5.5	5.8
3 months.....	6.7	4.4	3.5	5.2	5.4	5.4	5.9	5.4
5 months.....	6.8	4.5	3.6	4.8	4.6	4.7	5.7	5.4
8 months.....	7.2	4.8	3.6	4.5	4.4	4.8	5.4	4.4
11 months.....	7.7	3.6	3.5	4.8	4.8	4.6	4.6	4.4
14 months.....	8.7	2.6	3.4	3.6	4.4	4.0	4.4	4.3
17 months.....	8.8	2.8	3.4	3.5	3.7	4.3	4.4	3.3
50% sucrose—stored in light:								
1 week.....	5.3	5.8	3.3	5.9	5.2	5.3	6.0	4.4
2 weeks.....	5.6	5.4	3.4	6.0	5.3	5.2	6.1	5.2
1 month.....	6.1	4.8	3.6	5.8	5.2	5.3	6.0	5.0
2 months.....	6.9	4.4	3.5	5.2	5.1	5.0	5.9	4.9
3 months.....	6.6	4.6	3.6	5.3	5.4	5.2	5.3	5.1
5 months.....	7.1	3.9	3.6	5.2	5.2	4.9	4.6	4.2
8 months.....	8.2	3.6	3.5	4.4	4.5	4.4	4.1	4.3
11 months.....	8.9	3.9	3.5	3.8	4.1	4.0	4.0	3.8
14 months.....	9.4	2.8	3.4	3.5	3.8	3.8	4.1	3.5
17 months.....			3.4			3.8	4.1	3.5
50% sucrose—cold storage:								
1 week.....	5.4	6.2	3.3	5.9	5.4	5.5	6.1	5.2
2 weeks.....	5.4	5.9	3.4	5.9	5.8	5.4	5.9	5.8
1 month.....	5.4	6.1	3.5	5.7	5.5	5.4	6.0	5.8
2 months.....	5.6	5.7	3.5	6.1	5.6	6.0	6.3	6.0
3 months.....	5.8	5.8	3.5	6.5	5.8	5.9	6.4	6.1
5 months.....	6.0	5.5	3.5	6.1	5.9	5.0	5.8	5.5
8 months.....	5.9	5.0	3.6	6.4	5.8	5.7	6.0	5.8
11 months.....	6.0	5.4	3.5	6.4	5.1	4.6	5.6	5.6
14 months.....	6.4	5.4	3.4	5.9	5.4	4.4	5.9	5.4
17 months.....	6.7	4.3	3.4	5.2	5.0	4.2	5.5	4.7
Enamel tin:								
1 week.....	5.5	6.4	3.3	6.0	5.8	5.4	5.9	5.4
2 weeks.....	5.5	5.4	3.4	4.9	5.6	5.5	5.9	5.0
1 month.....	5.8	5.5	3.5	4.5	5.5	5.3	5.5	4.7
2 months.....	6.1	4.7	3.8	3.8	5.5	5.0	4.8	4.0
3 months.....	6.6	4.1	3.5	4.3	4.8	4.6	4.5	4.0
5 months.....	6.6	3.6	3.5	4.1	4.2	5.1	4.7	4.1
8 months.....	6.3	3.1	3.6	4.2	5.3	4.7	4.4	3.8
11 months.....	6.9	3.1	3.7	3.6	4.8	4.1	4.2	3.3
14 months.....	6.4	2.5	3.5	3.6	4.6	4.1	4.0	3.9
17 months.....			3.5	2.0	4.0	2.5	4.2	
Holding after opening:								
0 days.....								
1 day.....	7.2	4.8						
3 days.....	7.0	4.5						
5 days.....	7.0	4.2						
7 days.....	7.3	3.9						
9 days.....	7.3	4.1						
11 days.....	7.6	4.6						
14 days.....	7.7	3.7						
16 days.....	7.5	4.2						
18 days.....	7.2	4.1						
19 days.....	7.6	3.7						

*Each number is the average of eight figures, as two investigators observed the color of four replicate jars.

**Each number is the average of eight figures, as four judges tasted two composites for each test.

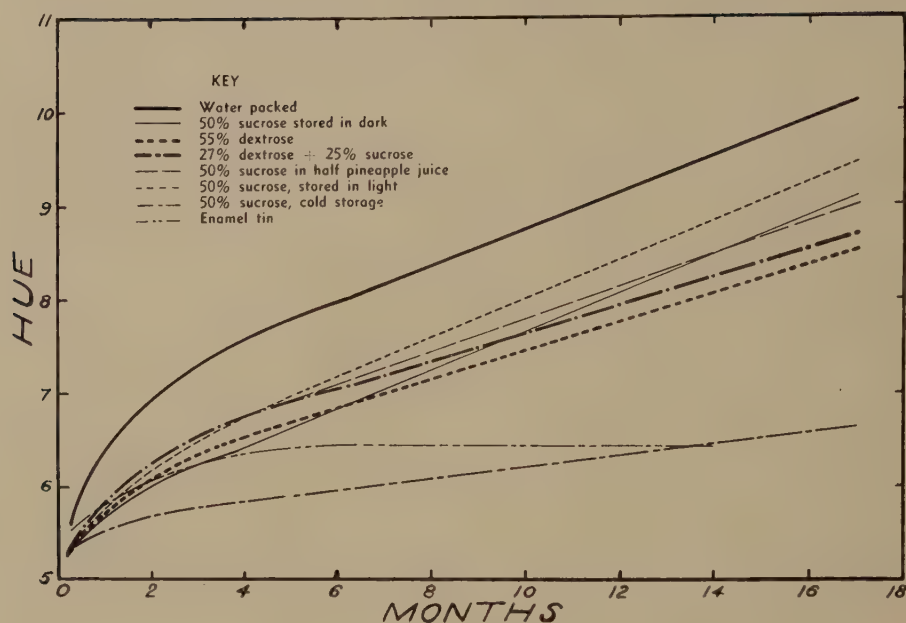


Fig. 1. Hue of cherries canned in various ways and stored for 17 months.

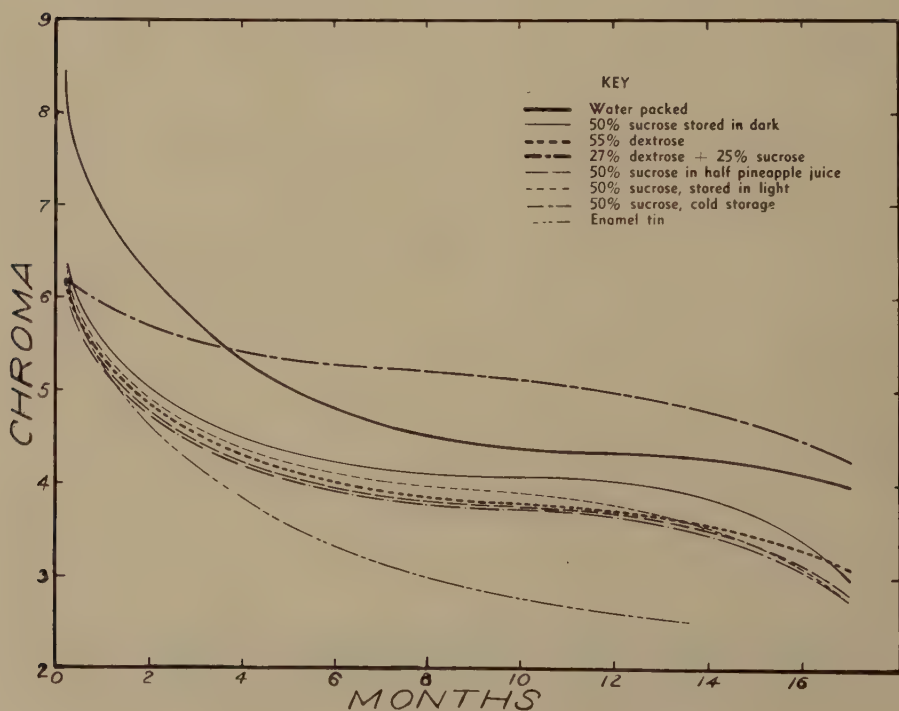


Fig. 2. Chroma of cherries canned in various ways and stored for 17 months.

a decline was noted in the palatability factors for all the variations during the course of the 17-month storage period. The smoothness of the curves for the various palatability factors shows that the judges were remarkably consistent in their grading over the 17-month storage period and evidently had the same standard in mind throughout the experiment. Comparisons for so long a period represent a rather severe test of the validity of subjective judgments. Graphs for the hue and chroma of the cherries, and for the judges' grades of general acceptability are shown in Figs. 1, 2, and 3.

In these graphs, smoothed curves drawn freehand are shown. The decline in general acceptability as well as in other palatability factors during storage was accompanied by an increase in hue number, indicating a change from a reddish to a yellowish color, and a decrease in chroma, showing that the colors became weaker during storage. It is interesting to compare the hue and chroma of the canned fruit after one week of storage with those of the raw cherries. The hue of the raw cherries (Table 8) was 5.3, the same or very similar to that of the canned fruit at the start of the storage period. The chroma of the raw cherries was much lower than that of the canned fruit, possibly because of the reflection of light from the rounded surface of the cherry, which made the color appear lighter than it really was. In making the color

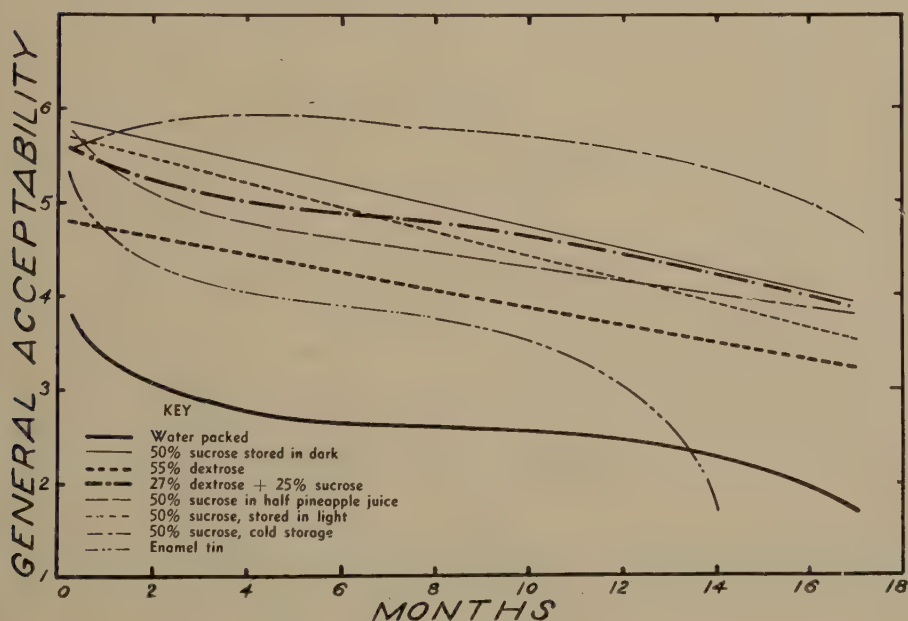


Fig. 3. Judges' scores for general acceptability of cherries canned in various ways and stored for 17 months.

TABLE 8—Objective color data and judges' scores for experimental and commercially canned cherries

Material	Approx. storage period	Number of jars	No. color readings in average	Objective color			Judges' scores					General acceptability		
				Hue	Bril- liance	Chroma	Desira- bility of color	Appear- ance	Texture		Flavor			
									Flesh	Skin	Fruit		Juice	
Raw cherries	(months)		30	5.3		3.8								
Sugar added—														
as sirup	9	8	16	7.1		6.0	5.6	5.3	4.6	5.2	4.9	5.0	4.3	
to water-pack	9	8	16	7.7		5.0	4.5	4.7	4.2	4.8	4.1	4.8	3.7	
Storage conditions—														
light	9	12	24	7.2		5.3	5.2	4.9	3.8	4.8	4.4	4.6	3.9	
dark	9	12	24	7.2		5.5	5.1	4.8	4.1	4.8	4.5	4.8	4.0	
Container—														
glass	11	4	8	7.8	2.8	4.1	5.1	5.2	4.2	4.8	5.2	5.2	4.6	
enameled tin	11	4	8	6.5	2.2	2.4	3.6	3.6	4.6	3.7	4.1	4.0	3.3	
plain tin	11	6	12	13.1	3.5	3.3	1.1	1.2	3.8	3.1	3.1	3.2	1.9	
Water pack	11	4	8	9.1		4.4	3.4	3.6	3.9	3.5	3.4	3.4	2.8	
Water pack	9	6	12	8.2		3.9	3.1	3.2	5.2	4.9	3.4	3.2	2.9	
Brand 1	24	1	4	9.0		3.4	1.8	1.9	2.1	3.2	2.2	2.8	1.5	
2	24	1	4	9.1		5.3	3.2	4.0	4.2	4.0	4.0	4.2	3.0	
3	24	1	4	9.8		4.5	1.8	2.2	2.8	3.2	2.5	2.4	1.9	
4	12	1	4	7.3		4.6	4.5	4.8	4.5	4.0	3.8	3.5	3.2	
5	12	1	4	7.9		5.0	3.8	4.5	5.0	5.0	4.0	4.2	3.5	
6	2	1	4	5.8		7.0	4.2	4.2	4.5	4.5	3.5	3.5	3.5	

determination, the flesh of the cherry was cut away from the stone and partly flattened out but the reflection was still troublesome.

Water-packed cherries compared unfavorably with the standard 50-percent sirup pack in color and palatability throughout the storage period. This was expected, for an Kohman and Sanborn (1935) say, every canner knows that sugar in colored fruit preserves the bright color in canning. Figure 1 shows that the color of the water-packed fruit was more yellow and less red (higher hue) after one week of storage, and that there was a similar difference in the color of the water- and sirup-packed cherries throughout the storage period. In this case, objective color readings were made one day after the fruit was canned, and show higher hues for the water-packed fruit at this early date. These results indicate that the sugar used in the sirup-packed cherries may have prevented loss of color during canning rather than protecting it from undesirable changes during long storage. The judges' scores for desirability of color agree well with the objective color readings, since they graded the water-packed fruit far below that packed in 50-percent sirup, and found about the same difference between the two packs one week and 17 months after canning. Other palatability factors, even texture of the skin and flesh, received low scores.

The preservative effects of sugar on the color of canned cherries, as observed in these experiments, was compared with its possible restorative effect by examining water-packed fruit to which sugar was added after opening, and sirup-packed cherries stored for the same length of time. The data (Table 8) show plainly that the addition of sugar before serving does not restore the quality of the fruit to the level of fruit canned in sirup. It is evident that sugar helps to preserve the quality of cherries during canning and storage. Kohman and Sanborn (1935) say that some chemical interaction is probably involved in the preservation of color by sugar in canning, as a later addition of sugar never restores the original bright color.

Theoretically, dextrose might be expected to have even more effect than sucrose in preserving the color of cherries, either by depressing the decomposition of anthocyanin to anthocyanidin plus monosaccharide, or by protecting the pigment from oxidation. However, the substitution of dextrose for half or all of the sugar had a deleterious effect on the color and palatability of the cherries (Table 7). There was not much difference in the hue of cherries canned in these sugars, but the chroma of the fruit in sucrose was higher, indicating a stronger color than that of fruit canned in 55-percent dextrose. Cherries canned in 55-percent dextrose sirup were graded below those canned in 50-percent sucrose sirup for all palatability factors. For most items, scores for fruit in 25-percent sucrose and 27-percent dextrose were between those

for fruit in 55-percent dextrose and in 50-percent sucrose. White powdery material was noticed around the rubber of some of the jars containing 55-percent dextrose sirup after they had been stored for 2½ months. Evidently a sirup with more sucrose and less dextrose would have been desirable. Fellers, Miller and Onsdorff (1937) found that Montmorency cherries canned in 60-percent sirup containing 3 parts sucrose to one part dextrose were preferred to an all-sucrose pack, and that a sirup containing 2 parts sucrose to 1 part dextrose was acceptable. On the other hand, Van Arsdale and Eddy (1933) found that cherries canned in a sirup containing 1 part dextrose and 1 part water were acceptable, while those in a sirup containing 3 parts dextrose for 1 part of water were not acceptable. Bruce (1938) speaks of a test in which a variety of fruit products were packed in pure dextrose, pure sucrose, and various blends of the two sugars. A majority of the judges preferred a blend of the two sugars. A blend of one-third dextrose and two-thirds sucrose was the first choice, a 50-50 blend was the second choice, all-sucrose was the third choice, and all dextrose the fourth.

Pineapple juice was used in an experiment because of its action in preventing the browning of fruits. However, the use of half pineapple juice and half water in the 50-percent sirup packs was not desirable because the cherries canned in this way had a less intense color (lower chroma) and compared unfavorably in most palatability factors with the standard pack. The flavor of the fruit canned with pineapple juice was quite different from that of the standard pack, and the natural cherry flavor was preferred by the judges.

It is usually recommended that canned goods be stored in a cool, dark place for, as Kohman and Sanborn (1929) say, not only is the life of the can extended by storage at lower temperatures, but the natural color of the fruit is preserved. The truth of this statement was demonstrated by the fact that the color of canned cherries stored in a dark refrigerator at 50° F. (10° C.) was redder and stronger (lower hue, higher chroma) than that of fruit stored in the dark at room temperature. These differences were apparent after 2 weeks and became much greater as time elapsed. As storage progressed, the contrast between the bright red of the cold storage cherries and the faded brownish color of the other fruit became striking. As might be expected, there was little difference in the texture of the samples, but rather large differences in desirability of color, appearance, flavor and general acceptability. Scores for all samples were close at first, but after a period ranging from 2 weeks to 3 months for the various palatability factors, the fruit stored in a cool, dark place was rated far ahead of the samples stored at

room temperature, and the difference became more marked as the storage period lengthened.

Cherries stored in the light had a somewhat yellower, less intense color (higher hue, lower chroma) than those stored in the dark at the same temperature (Table 7). In most cases, the judges preferred fruit stored in the dark to that stored in the light, but the differences were small throughout the storage period. To check the results, the experiment was repeated in 1942 on fruit stored for 9 months. The data (Table 8) show very small differences in objective color grades and judges' scores. Evidently the effect of temperature is more important than that of light.

The color of cherries canned in enameled tin was purplish and much less intense than that of the standard glass packs (Table 7). For most of the other experiments already reported in which an undesirable color developed, the hue became yellowish, but with cherries canned in enameled tin, an undesirable purplish tint caused the hue number to be low for a different reason than has been observed in the other experiments. Brilliance was calculated for cherries stored in enameled tin for 11 months (Table 8) and indicated a somewhat darker color than for the standard. This difference was quite evident to the eye. Palatability scores for all factors were lower for cherries canned in enameled tin than for the standard packs. For most factors, the differences were large, especially toward the end of the storage period.

After storage for 8 months, breaks were noticed in the enamel, and holes were evident after 11 months. After 17 months of storage, the cherries canned in tin were not examined because all the remaining cans had perforated. Since the type of can used is recommended for cherries, it is probable that the canning method was at fault. The most likely cause of the trouble seems to be the inclusion of excessive air during canning (Sanborn, 1943). About $\frac{1}{4}$ -inch head space was allowed in filling the cans, as recommended by Stanley, Stienbarger and Shank (1941). However, $\frac{1}{4}$ -inch head space in $\frac{1}{2}$ No. 2 cans ($\text{No. } 307 \times 208$) allows too high a ratio of entrapped air to the interior surface, and it would be better after exhausting, to add additional boiling sirup to fill the can completely (Sanborn, 1943). The presence of even small amounts of air in canned fruit is evidently very harmful. Lueck and Pilcher (1941) say that the presence of oxygen in cans of orange and lemon juice in amounts exceeding 0.10 percent by volume promotes an attack on the container which disrupts the bond between the enamel film and the tin plate. Culpepper and Caldwell, working in 1927 when enameled cans were probably not of as high quality as they are now, noticed slight purpling in Montmorency cherries canned in enameled tin, and found that even in the best enameled cans there was more loss of color in red fruits than

occurred in glass. They also speak of the certainty that perforation will sooner or later occur in red fruits canned in enameled tin, and explain the chemistry involved in the pinholing of the enamel lining. They compared exhausted and unexhausted cans, and concluded that the presence of oxygen, together with anthocyanin, greatly accelerates corrosion.

Cherries canned in plain tin and stored for 11 months (Table 8) had a light yellowish, less intense color (higher brilliance and hue, lower chroma) than the glass pack. The lightness of the color was particularly striking. The palatability of fruit in plain tin cans compared very unfavorably with that in enameled tin. Culpepper and Caldwell (1927) also noticed pronounced fading of cherries canned in plain tin and stored for 8 months, and said that in all their experiments the anthocyanin colors were somewhat better preserved in enameled cans than in plain tin.

The pH determinations that were made on all experiments in the storage series (Table 7) did not show any marked differences. The pH of the raw cherries was 3.3, about the same as that of the canned cherries at the start of storage. There was little difference between the pH of the canned cherries in the various experiments. The pH of cherries canned in enameled tin was more erratic throughout the storage period than that of the cherries canned in glass, possibly owing to the varying reaction of the fruit constituents with the tin. There was some tendency for the pH of the fruit in all the experiments to increase until the eighth month after canning and then to decrease. The greatest difference in pH was 0.4.

The work described on canning cherries in tin raised the question of the quality of commercially canned fruit. The measurements of the quality of this fruit are included in Table 8. Two samples of the experimental water-packed fruit are also included in this table for comparison, although these cherries were packed in glass. All experimental samples in tin cans were packed in sirup. The objective color data indicate that the commercial cherries stored 2 months had the brightest red color, as indicated by a high chroma and low hue. The brands of cherries which had been stored 2 years, and the experimental fruit, had a more yellowish color (higher hue) than did the brands stored for one year. On the whole, the commercial cherries stored for 2 years were of lower quality than were those stored for shorter lengths of time. Brand 2 was better than the other samples stored for the same length of time. Brand 3, which was packed in juice, was no better than other samples stored for the same length of time. Brands 4, 5, and 6, which had been stored for 2 or 12 months, scored fairly high in palatability, and were better in several factors than the experimental packs which had been stored for 9 and 11 months.

The data indicate considerable variation in the quality of commer-

cially canned cherries, and suggest deterioration in quality with increased storage period. Much of the observed variation may be accounted for by the quality of the fruit used. It is possible that different varieties or strains of sour cherries were used, and probable that there was considerable variation between samples obtained from various localities and in different seasons.

The effect of refrigerator storage of cherries in a jar that had been opened was studied by making objective color readings every 2 or 3 days for 19 days after opening the jar (Table 7). The fruit was not scored for palatability. Although the curves are somewhat irregular, it is evident that the color became weaker and more yellowish, as indicated by increased hue and decreased chroma. The fruit did not seem spoiled after 19 days' storage in a refrigerator.

IV. DISTRIBUTION OF THE RED PIGMENT IN RAW AND CANNED CHERRIES

Examination of a raw Montmorency cherry shows that the red color is concentrated in the skin of the fruit, while the flesh of the cherry is yellowish in color. In the canned fruit, however, the red pigment is visible throughout the cherry, and also colors the sirup. In connection with a study of the effects of canning on the color of cherries, it seemed desirable to study, histologically, the location of the pigment in the fresh and canned fruit.

The morphology of the cherry has been studied by Moeller (1928), Kosemanoff (1939), Tukey and Young (1939) and others. Tukey and Young made this statement about pigment distribution: "In fresh unstained material the cell contents appear yellowish or straw-colored, in contrast to the bright red color of epidermal cells well supplied with chromoplasts." A search of the literature has revealed no histological studies of canned or cooked cherries.

EXPERIMENTAL PROCEDURE

Montmorency cherries for the fresh sample and for canning were taken from the College Orchard. The canned fruit was the standard pack, pitted cherries in 50-percent sirup, and had been stored 2 months when examined.

Technical difficulties were encountered in the histological examination of cherries. Obtaining a section one or two cell-layers thick of a fruit that has a resistant skin and a very soft flesh was troublesome, but the solubility of the anthocyanin in water and other solvents caused the greatest difficulty. This solubility made fixation methods impossible, and when a freezing microtome was used, cell sap was thawed instantly

and spread by the knife, dissolving the pigment in the epidermal cells and spreading it over the other cells. When these preparations were washed with distilled water, much of the color disappeared from all tissues, regardless of its original location. Freehand sections were not successful for similar reasons.

Because of these difficulties, attempts were made to precipitate the pigment within the cell. The most successful chemical for this purpose proved to be saturated neutral lead acetate, a substance long known to precipitate anthocyanins from solution and one that was suggested for use in microchemistry by Molisch (1923). A cube of cherry about 4 millimeters on each side was soaked in saturated neutral lead acetate for about 1½ hours. This treatment changed the color of the anthocyanin to blue. The cube of cherry was rinsed, and frozen with carbon dioxide in a freezing microtome. Sections were removed carefully from the knife to a slide with a drop of water, and washed with more water on the slide. The water was drained off and replaced by equal parts of glycerol and water. A cover glass was put on, and the section was photographed. A copy camera (F7.7 lens) was used in connection with a microscope. The film was Kodak Panatomic X, and a green filter was used between the light source and the slide. The magnification was about 200.

DISCUSSION OF RESULTS

The photomicrographs are shown in Figs. 4 and 5. These pictures and examinations of other sections show that the fresh cherry is surrounded by a continuous waxy cuticle. The outer epidermis, one cell-layer thick, consists of more or less rectangular cells filled with red pigment. Adjacent to this cell layer is one layer of hypodermal cells which are tangentially elongated and more irregular in shape. Kosemanoff (1929), working with Montmorency de Sauvigny and Montmorency de Bourgueil cherries, also found that the epidermis and subepidermis were each one cell-layer thick. In Fig. 4, the hypodermal cells appear to be colored, but it could not be proved conclusively whether these cells are colored in the fresh fruit, or whether pigment diffused from the epidermal cells of the cut cherry before the lead acetate penetrated far enough to precipitate it completely. The parenchymatous cells are roundish or oval and straw-colored.

In the canned fruit (Fig. 5), the anthocyanin is no longer restricted to cells of one type, but is distributed throughout the tissues. This is probably caused by changes in the permeability of the cell walls brought about by heat and by changes in osmotic pressure due to the addition of sirup in canning. The cells of the canned fruit appear enlarged and less definite in contour than in the fresh cherry. Their walls are swollen and extended.

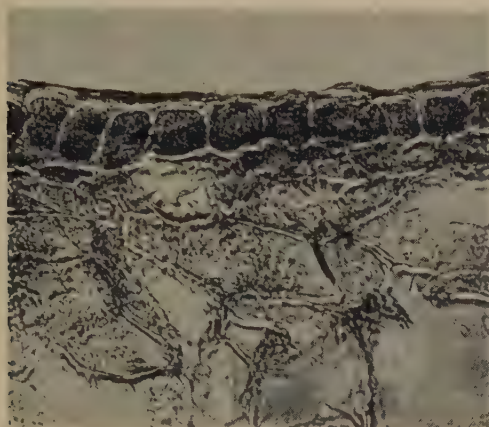


Fig. 4. Photomicrograph of a section of fresh cherry. Magnification approximately $\times 200$.

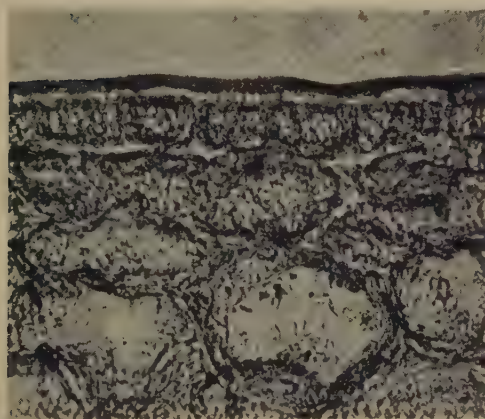


Fig. 5. Photomicrograph of a section of canned cherry. Magnification approximately $\times 200$.

SUMMARY

Factors which influence the quality of home-canned Montmorency cherries were studied by making variations in method and ingredients from a standard canning procedure. In some of the experiments, the fruit was stored 9 or 10 months before examination, while in other cases, changes in quality were followed for 17 months. The tests which were made included objective color measurements by the Munsell system, palatability, and acidity as measured by pH in certain cases. Color was also studied by following, histologically, changes in the distribution of the red pigment in raw and canned cherries. A method

of precipitating the pigment within the cell before sectioning was developed.

Cherries canned immediately after picking had a redder, more intense color (lower hue, higher chroma), and tasted better than those held 4 days at 41° F. or those held at 84° F. for 24 hours before canning. The canned fruit was better when the cherries had been soaked in cold running water for 3 hours before canning than when the cherries had not been soaked or had been soaked for longer periods. The color became more orange, and somewhat less intense with increased soaking.

The wide range of processing times, 10 to 45 minutes, resulted in less variation in quality than might have been expected. The hue was somewhat more orange (higher) for underprocessed and a little redder (lower) for overprocessed fruit. Cherries processed 10 minutes did not seem spoiled, and those processed 45 minutes compared rather closely with those processed for the standard 25 minutes. The shortest processing time could not be recommended from the standpoint of safety, and the longest periods did not improve the fruit. The standard time, 25 minutes, was satisfactory.

A decline in the quality of the canned cherries with an increase of head space from $\frac{1}{4}$ to $1\frac{1}{4}$ -inch was noticed. The color became consistently more orange and less intense as the head space increased.

The standard cold-pack method produced a better product from the standpoint of color and palatability than pressure cooking or a hot-pack method using either sugar or sirup. The use of an anti-browning agent or a larger proportion of sirup was not beneficial.

Tap water and distilled water to which had been added several of the constituents of tap water had about the same effect on the color and palatability of water-pack cherries as distilled water itself. The use of distilled water to which one part per million iron had been added lowered the palatability scores. The flavor of cherries canned in water containing stannous chloride or calcium chloride was undesirable.

The addition of increasing amounts of malic acid, citric acid, or lemon juice made the color of the fruit less intense (lower chroma) and less desirable. Palatability scores decreased as the amounts of acid increased.

The color of fruit in more concentrated sugar sirups was less intense and darker (lower chroma and brilliance) than in the more dilute sirups. As the percentage of sugar increased from zero to 70, scores for the various palatability factors increased at first and then decreased at the highest concentrations. The judges preferred fruit canned in 40- or 45-percent sirup.

Canned underripe cherries had a stronger, more yellowish color, while overripe cherries had a redder, less intense color than fruit of

standard ripeness. The color of canned unpitted cherries was a little redder and less intense than that of the standard. The judges preferred fruit of standard ripeness to underripe or overripe fruit, and liked canned unpitted cherries.

During a storage period of 17 months, the color of cherries canned in various ways became weaker and more yellowish (lower chroma, higher hue), and the palatability less desirable. Water-packed cherries compared unfavorably with the standard 50-percent sirup pack in all factors throughout the storage period. The objective measurements indicate that sugar sirup probably prevented the loss of color during canning rather than during storage. The addition of sugar to water-packed fruit before serving did not restore the quality of the cherries to the level of fruit canned in sirup.

The substitution of dextrose for half or all of the sugar, or the use of some pineapple juice in the sirup did not improve the quality of the cherries.

Canned cherries stored in a cool, dark place retained their color well during the long storage period, while the color of samples stored at room temperature became yellower and less intense. Cherries stored in the dark retained their color better and were more palatable than those stored in the light at the same temperature but differences were not great. The judges considered the canned fruit stored in the dark at a constant, cool temperature far superior in all respects to that stored at room temperature either in the light or dark.

Cherries canned in plain tin were very poor, and those canned in enameled tin compared unfavorably in color and palatability with those in glass. Difficulty with perforation of the enameled cans indicated that excessive air may have been included during canning in tin.

A study of cherries commercially canned in water or juice showed great differences between the quality of brands, and some evidence of deterioration on long storage.

Color readings on cherries opened and held in a refrigerator for $2\frac{1}{2}$ weeks indicate that the color became weaker and more yellowish during this period.

Histological sections prepared to show the distribution of the red color in raw and canned cherries showed that the anthocyanin of the raw fruit occurs largely, if not entirely, in the outer epidermis, while the parenchymatous cells are straw-colored. In the canned fruit, the anthocyanin is no longer restricted to cells of one type, but is distributed throughout the tissues. The cell walls are swollen and extended, and the cells appear enlarged in the canned fruit.

RECOMMENDED METHOD FOR CANNING MONTMORENCY CHERRIES IN GLASS JARS

1. Use cherries as soon after picking as possible. If convenient, soak the fruit for 3 hours in cold running water before pitting. Wash fruit if it has not been soaked.

2. Heat glass jars in boiling water or a steamer for at least 20 minutes. Process the jar tops in this way unless they have a flowed-on gasket which is harmed by much heating. Dip rubber rings in boiling water just before use.

3. Prepare a 40- to 45-percent sugar sirup by adding $3\frac{1}{4}$ to $3\frac{3}{4}$ cups sugar to 1 quart water.

4. Pit cherries. A hand-operated household pitter is convenient, but a sterilized hairpin, a paper clip straightened at the center bend, or a knife may be used. Fill hot jars with pitted cherries. Use no more jars than can be handled promptly.

5. Bring sirup to a boil and pour over cherries to a level one-fourth inch from the top of the sides of the jar. Adjust rubber rings and partially seal jars.

6. Immerse jars in a container of boiling water having a rack in the bottom. The water should extend 1 or 2 inches above the tops of the jars.

7. Process jars 25 minutes after boiling has resumed.

8. Remove jars from water, and complete seal.

9. When cool, put jars in a cool, dark, dry place. A low storage temperature is very important in maintaining quality.

NOTE: *This method of canning cherries is the one found most satisfactory in this study. Other types of glass jars and enameled-lined cans may be very satisfactory when used according to reliable directions. Cherries may be canned in more dilute sugar sirups or in water if the sugar supply is limited.*

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FACTORS INFLUENCING THE QUALITY OF COOKED JONATHAN APPLES

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SECTION OF FOODS AND NUTRITION

EAST LANSING

CONTENTS

	PAGE
Introduction	3
General Experimental Procedure	4
Discussion of Results	7
Condition of the Apples	7
Preparation of the Apples for Cooking	9
Cooking Methods	12
Addition of Sugar and Acid	15
Storage of Applesauce	17
Summary	17
Acknowledgment	18
References	19

Factors Influencing the Quality of Cooked Jonathan Apples

By RUTH M. GRISWOLD

The large quantity of apples used in Michigan and other states makes information about the quality of cooked apple products important to the consumer. In an attempt to determine the effect of different cooking methods on the quality of cooked apples, one of the simplest products, applesauce, was selected for investigation. Using the same kind of apples, Jonathans, throughout, the effect on the color and palatability of applesauce of such variables as the condition of the fruit, its preparation for cooking, the cooking method, and additions of sugar and acid were studied.

Since the color of the cooked fruit was of especial interest in this study, a consideration of the pigments of the apple and the factors which influence the color of these pigments is of first importance. The chemistry of the pigments of Jonathan apple peels has been studied by Sando (1937), who identified the anthocyanin pigment as 3- β -galactosidylecyanidin or idaein, and the flavonol glycoside as 3-galactosidylquercetin. It is well known that the color of these pigments depends in part on the acidity, anthocyanins usually being red in acid, and blue, greenish blue or violet in an alkaline medium, while flavones are almost colorless in acid, but yellow or red in base. Apples have a rather acid reaction, the juice of stored raw Jonathan apples being pH 3.33 (Barnes, 1940). During six weeks of additional storage, the acidity decreased, as indicated by a pH of 3.45. Barnes also tested cooked apples and found that the juice of cooked apples was usually slightly less acid than that of the raw, but the change was so small that it might be explained by loss of carbon dioxide. Careful studies of the suitability for cooking of varieties of locally grown apples have been made in at least three states. As early as 1915, such a study was made by Milam and Gardner, who used Oregon apples for sauce, pies, dumplings, jelly and marmalade. They found that apples which make good sauce usually make good pie and dumplings because similar methods of cooking are employed for these products. There was little correlation between sauce- and jelly-making quality, or between cooking and dessert quality. Child and Brand (1937, 1938) studied the value of Minnesota apple varieties for sauce, pie, baked apples and jelly, and developed standard methods

for making these products. New York apples were studied by Pfund (1939), who made physical and chemical measurements which might contribute toward an explanation of the character of the cooked apple products. She found that good flavor and pleasant texture in cooked apples were associated with relatively high acidity, both factors being satisfactory in the range pH 3.10 to 3.30. In each of the three states mentioned, Jonathan apples, the variety chosen for this study, were found to have very desirable cooking qualities for sauce, pie, baked apples and dumplings.

GENERAL EXPERIMENTAL PROCEDURE

Jonathan apples from the Michigan State College orchards were used. All the apples except those used in an experiment on ripeness were picked at one time and stored at 35.6° F. (2° C.), 85- to 95-percent relative humidity. Fruit was removed at random for the experiments which extended from October 1941 to April 1942.

The standard method of preparing sauce was similar to that used by Pfund (1939). Six hundred-eighty grams of apples were cut with a stainless steel knife into quarters or eighths, depending on size. The stem and blossom ends were removed, but not the core or skin. The apples were added to 177 milliliters of boiling distilled water, in a chip-free enamel-lined 2-quart saucepan, and cooked, covered, for 18 minutes. A gas burner especially regulated to give a uniform low heat was used. The pulp was strained through a wire sieve, 450 grams of pulp were weighed, and 45 grams beet sugar were added. This standard method was always followed except where otherwise specified.

The variations from this method were divided into series, each of which included a standard. Since a series often required several weeks for completion, an equal number of replicates was done each day of the experiment, until a total of eight replicates had been completed for each sauce. This precaution prevented the storage period of the apples from causing error. For convenience, the series of variations have been grouped under five headings. In each case, the standard method was followed except for the variation noted. The standard, which was included in each series, is not always mentioned below.

A. Condition of the apples

1. Apples stored 18 to 165 days were used. The control of each series made up this experiment.
2. Under-ripe and over-ripe fruit was compared with that of standard ripeness. The skin of the under-ripe apples was slightly green, while that of the over-ripe fruit was dark red.

B. Preparation of the apples for cooking

1. Peeled, cored apples were compared with unpeeled, cored apples and the standard unpeeled, uncored fruit.
2. Apples cut as usual were soaked 24 hours in 2.5-percent salt (NaCl) solution and rinsed twice before cooking.
3. Anti-browning agents were used. The cut apples were put in one of the following liquids for 30 seconds, drained and cooked. Distilled water was used for cooking the Frulite samples, but the pineapple and lemon juice solutions were brought to a boil after the apples were removed, and the fruit cooked in the solution in which they had soaked.
 - a. One Frulite* tablet (0.5-gram tablet of thiocarbamide plus starch) in one quart distilled water.
 - b. Solution of 12-percent unsweetened pineapple juice in distilled water.
 - c. Solution of 12-percent unsweetened lemon juice in distilled water.

C. Cooking method

1. Variations in method
 - a. Pan was left uncovered during the cooking period.
 - b. Apples were steamed on a plate in a small steamer. Forty-five minutes to one hour was required to make this sample as tender as the control.
 - c. Apples were cooked in a four-quart "Presto" pressure saucepan for two minutes after pressure was up, after which the cooker was put in cold water.
2. First metal series
 - a. A glass knife was used for preparation and a cotton net was used for straining. No metal was in contact with the apples at any time.
 - b. An aluminum pan was substituted for enamel.
 - c. The cut apples were cooked in water containing 0.9 gram sodium bicarbonate.
3. Second metal series
 - a. A cotton net was used for straining. Differs from C2a in that stainless steel knife was used.
 - b. An enamel colander was used for straining.
 - c. A pressure saucepan was used as under "variations in method".
 - d. A pressure saucepan was used like a regular saucepan, without pressure.

*Obtained from the Boyce Thompson Research Foundation Incorporated, Yonkers, New York.

4. Cooking times of 13, 23, 28 and 33 minutes were compared with the standard 18 minutes.

D. Addition of sugar and acid

1. Sugar was added at the start of cooking. Additional sugar was used on the assumption that the proportion of sugar to pulp remaining in the sieve would be about the same as the proportion of sugar in the sauce. The resulting sauce was of about the same sweetness as that of the standard.
2. Sauces were made without sugar and with twice the usual amount of beet sugar. For comparison, this series was also made with chemically purified sucrose. Five, instead of eight, replicates were used and the sauces were not tasted.
3. Solutions of 0.67-percent citric acid, of 0.35-percent ortho-phosphoric acid, and of 0.48-percent l-malic acid were used instead of water in making up the sauces.

E. Storage of the sauce

1. Sauces in covered pint glass jars were examined after one, three and five days storage at 50° F. (10° C.). Six instead of eight replicates were used.

The color of each sample of applesauce was determined independently by two observers, using the Munsell color system. The method which has been described in detail by Griswold (1944) will be outlined briefly here. Applesauce for the test was placed in a Pyrex custard cup, levelled off with a spatula, and the position of the cup adjusted so that the surface of the sample was level with the disks. Four Munsell color disks, overlapped by radial slits, and whirled by a motor, were used to match the sample. In the Munsell system, color is described by means of its three attributes, hue, brilliance and chroma. *Hue is the name of a color and is designated by a number.* For instance, the hue number of red is 5, that of yellow-red 15, and that of yellow 25. *Brilliance is the lightness or darkness of a color.* Brilliance numbers go from 1, which is black, to 10, which is white. *Chroma is the strength or purity of a color.* Its units begin with neutral gray, which is zero, and increase to 6 or even 14, depending on the maximum chroma possible with each color. In this system any color can be designated by three numbers which are written in the sequence hue, brilliance, chroma. Hue may be designated by either a word or a number. It is followed by numbers indicating the brilliance and chroma of the disks. The color of the samples varied so much that the same set of disks could not be used for all samples. One of the following three sets of disks was selected for each sample:

1. red 4/14, yellow-red 6/12, neutrals 5 and either 1 or 9.
2. yellow-red 6/12, yellow 8/12, neutrals 1 and 7.
3. yellow 8/12, green-yellow 7/10, neutrals 1 and 7.

The hue and chroma of the sample were found from the area of the disks by the use of a table (Nickerson, 1935).

The pH of some of the sauces was measured, using a Beckman glass-electrode pH meter.

The palatability of the sauces, under code numbers, was rated by four experienced judges. The factors: color, appearance, texture, and flavor were each rated on a scale of adjectives going from very undesirable with a grade of one to very desirable with a grade of seven. The general acceptability of the fruit was described by the judges on the basis of seven adjectives from "very poor" to "excellent". Two replicate samples were mixed for the judges so that they tasted four composites instead of the eight replicates made for each sauce.

A portion of the data, that on four cooking methods, is given in full as an example of the variations obtained in the objective color data and judges' scores and to show what differences may be expected to be significant. The standard errors of the means are included, and the significance of differences between corresponding means of the standard and the experimental methods was determined by Student's *t* test (Fisher, 1936).

DISCUSSION OF RESULTS

CONDITION OF THE APPLES

The effect of the storage of apples on the quality of sauce made from them may be studied by examining data (Table 1) for the controls of all the experiments, which were done over a six months' period.

As the storage period progressed, the color of the sauces became more yellow and less intense. At the same time, the apples became less desirable to the judges, as indicated by highly significant negative correlations of storage period with desirability of color (-0.699) and with general acceptability (-0.558). Other palatability factors also received lower scores as the storage period lengthened. These observations agree with those of Pfund (1939) who noted that the flavor and texture of cooked apples became less desirable as storage progressed. It is significant that Jonathan apples retained their flavor better than some of the other varieties used in her study.

The data in this series were homogeneous except for variations in storage, and seemed suitable for correlating hue and chroma, the two factors used for expressing color objectively. The correlation found was highly significant, -0.774 . However, this correlation is open to the criticism that hue and chroma were both changing as storage progressed, and that these changes might have accounted for the significance of the correlation. To compensate for this trend, another correlation was found between hue and chroma, but this time the differences be-

TABLE 1—*Effect of the storage of apples on the quality of applesauce*

Length of storage of apples (days)	Number of replicates	Objective color		Judges' scores*				
		Hue +	Chroma††	Desirability of color	Appearance	Texture	Flavor	General acceptability
18.....	4.....	14.5	7.4	5.6	5.7	5.9	6.0	5.4
26.....	2.....	14.3	6.2	6.2	6.0	5.4	5.6	5.2
27.....	4.....	15.4	6.6	5.8	5.6	5.4	5.3	5.0
28.....	4.....	14.6	6.4	5.5	5.6	5.5	5.4	5.0
29.....	2.....	13.3	6.8	6.0	6.0	5.2	5.4	5.2
33.....	2.....	12.7	7.1	6.0	6.0	5.2	5.2	5.0
36.....	2.....	11.8	8.4	6.2	5.7	5.5	5.5	5.2
40.....	2.....	12.0	7.2	5.6	5.6	5.8	5.0	4.8
47.....	2.....	14.8	6.7	5.6	5.6	5.4	5.6	5.2
50.....	2.....	15.7	5.8	5.4	5.6	5.6	5.4	5.0
54.....	2.....	13.8	6.0	5.2	5.2	5.0	5.0	4.6
57.....	2.....	15.2	5.8	5.6	5.0	4.8	5.2	4.8
61.....	2.....	15.4	5.8	5.2	4.8	5.0	5.4	4.8
64.....	2.....	14.8	6.0	5.2	5.2	5.0	5.4	5.7
68.....	2.....	16.6	5.2	4.4	4.2	5.0	5.0	4.2
106.....	2.....	14.5	6.7	5.2	4.8	3.8	4.5	4.1
109.....	2.....	16.8	5.1	4.2	4.2	5.2	5.8	4.8
117.....	2.....	14.8	5.5	5.2	5.4	4.5	5.2	4.5
123.....	2.....	15.0	5.1	5.5	5.5	6.0	5.6	5.4
127.....	2.....	14.6	5.1	4.8	4.3	4.0	4.5	4.0
130.....	2.....	15.4	5.3	5.0	5.2	6.0	5.5	5.0
141.....	2.....	16.0	5.2	5.8	5.6	5.0	4.0	4.1
144.....	2.....	15.5	5.6	5.2	5.2	5.1	5.5	5.2
148.....	2.....	15.2	4.6	4.6	4.5	5.3	4.5	4.5
155.....	2.....	13.5	6.4	4.6	4.8	5.0	5.0	4.6
162.....	2.....	15.4	5.4	4.5	4.9	4.8	4.6	4.0
165.....	2.....	15.6	5.4	3.5	4.0	4.5	4.5	4.5

*Scores are on the basis of seven as the most desirable, and one the least desirable grade.

†The hue number of red is 5, that of yellow-red 15, and that of yellow 25.

††Chroma is the strength or purity of a color, neutral gray being zero, while higher numbers represent stronger colors.

tween the hue figures from the regression line of hue against time were correlated with similar differences for chroma (Fisher, 1936). The correlation corrected for storage time, -0.741 , was highly significant and very similar to that found by the standard method. Evidently there is a relationship between hue and chroma which is not due to the trend caused by storage time. The sign of the correlation indicates that as the hue became more yellow or less red (higher) the chroma became less intense (lower).

Since the apples were not peeled before cooking, it is not surprising that degree of ripeness affected the color as well as the palatability of the applesauce (Table 2). Sauce made from the over-ripe fruit had the reddest, most intense color, as indicated by the lowest hue and highest chroma, while sauce from under-ripe fruit had the yellowest, least intense color. Under-ripe fruit made sauce that was less desirable to the judges than fruit of standard ripeness. Sauce from over-ripe fruit was attractive, but graded low in flavor and general acceptability.

PREPARATION OF THE APPLES FOR COOKING

It has been mentioned that in the standard method of making sauce the apples were not peeled or cored before cooking. This method was used because much of the pigment of the apple is in the skin, and this experiment was concerned especially with the effect of various treatments on the color of the pigments as shown in the sauce. Since the ascorbic acid content of apple peels is higher than that of the flesh (Todhunter, 1939; Ehëart, 1941), it seems logical that sauce made from unpeeled apples would be higher in ascorbic acid than that made from peeled fruit, and unpublished work done in our laboratory has shown this to be the case. Other reasons for making sauce from unpeeled apples are greater ease of preparation and less waste.

However, the judges preferred sauce from peeled, cored apples to that made from unpeeled cored or uncored apples (Table 2). Pfund (1939) stated that sauce made from unpeeled apples of several varieties was inferior in flavor to sauce made from peeled apples, because of bitterness apparently acquired from the skins, but she did not mention Jonathan apples in this connection. Neubert and Mottern (1940) found that sauce made from unpeeled apples had a less desirable flavor, had defects and was more likely to have an undesirable color after canning in tin than sauce made from the peeled, cored fruit. In the present experiment, sauce from peeled apples had a much yellower color than that from unpeeled apples, as shown by a higher hue. The judges' scores indicate that they considered the greenish-yellow color of sauce made from peeled apples just as desirable as the more orange color of the unpeeled apples.

TABLE 2—Objective color data and judges' scores for appearance prepared in various ways

Variation	Objective color*		pH	Judges' scores**				General acceptability
	Hue	Chroma		Desirability of color	Appearance	Texture	Flavor	
Ripeness:								
Under-ripe.....	17.6	5.6	.....	4.7	4.8	5.2	4.8	4.6
Standard.....	13.0	7.1	.....	6.1	5.9	5.3	5.4	5.2
Over-ripe.....	7.5	9.8	.....	6.2	6.0	5.1	3.4	3.6
Peeling:								
Peeled, cored.....	24.9	5.3	.....	5.6	5.5	6.1	5.7	5.3
Unpeeled, cored.....	14.3	6.6	.....	5.6	5.4	5.4	5.5	5.0
Unpeeled, uncored.....	15.5	5.7	.....	5.1	4.8	5.0	5.2	4.9
Soaking:								
None.....	15.3	5.6	.....	5.1	5.0	4.9	5.3	4.7
24 hours in 2.5% NaCl.....	16.2	6.7	.....	5.8	5.6	4.6	4.6	4.6
Anti-browning:								
Standard.....	14.1	6.4	3.57	5.4	5.5	5.4	5.2	4.9
Thiocarbamide.....	13.1	7.2	3.54	5.9	5.8	5.4	5.3	5.1
Pineapple juice.....	14.2	6.8	3.54	5.6	5.7	5.3	4.8	4.6
Lemon juice.....	13.0	7.6	3.33	6.0	5.8	5.7	5.0	4.8
Metal series 1:								
No metal.....	13.7	7.0	3.66	6.2	5.8	5.6	5.8	5.7
Standard (metal knife and strainer).....	15.3	5.6	3.67	5.1	5.0	4.9	5.3	4.7
Metal knife, pan, and strainer.....	16.1	5.4	3.65	5.0	5.1	4.8	4.9	4.6
Soda.....	17.1	4.6	4.27	3.9	4.2	4.3	3.0	2.8
Metal series 2:								
Type of strainer—								
Metal (standard).....	15.0	5.5	3.67	4.3	4.5	4.9	4.7	4.3
Cotton net.....	13.0	7.2	3.64	5.8	5.1	5.1	5.2	4.9
Colander.....	14.6	6.5	3.63	5.1	3.9	3.8	4.8	4.2
Pressure saucepan with pressure.....	14.4	6.8	3.68	5.7	5.5	5.7	4.8	4.6
Pressure saucepan with no pressure.....	14.7	6.4	3.72	5.4	5.1	4.8	5.1	4.8

Cooking time:

13 minutes	16.4	5.4	5.7	5.8	4.7	5.5	5.1
18 minutes	15.3	5.6	5.1	5.0	4.9	5.3	4.7
23 minutes	15.1	5.7	5.1	5.1	5.2	5.3	4.9
28 minutes	15.0	5.5	4.2	4.5	4.5	4.3	3.9
33 minutes	15.6	5.0	3.6	3.9	4.4	3.9	3.5

Sugar added:

Before cooking	15.1	6.6	5.4	5.4	5.4	5.2	4.8
After cooking (standard)	15.5	5.7	5.1	4.8	5.0	5.2	4.9

Beet sugar:

0%	15.2	6.3	5.3	5.4	5.4	4.4	3.9
10% (standard)	15.0	6.5	5.6	5.6	5.4	5.3	5.0
20%	14.9	6.4	5.8	5.7	5.8	5.2	5.0

Acid:

Distilled water (standard)	14.1	6.4	5.4	5.5	5.4	5.2	4.9
Citric acid	13.3	7.8	3.57	5.5	5.7	5.2	4.9
Malic acid	13.3	7.6	3.32	5.8	5.7	5.2	4.9
Ortho-phosphoric acid	13.5	7.2	3.38	5.8	5.5	4.7	4.6
			3.27	5.7	5.5	5.1	5.0

Storage of sauce:

None	14.5	7.4	5.6	5.7	5.9	6.0	5.4
1 day	14.7	7.0	6.1	6.1	6.0	6.2	5.1
3 days	14.5	6.5	5.4	5.4	5.2	5.1	5.3
5 days	15.4	5.8	5.2	5.4	5.5	4.4	4.5

*Each number is the average of 16 figures, as two investigators observed the color of eight replicates.

**Each number (except for storage of sauce) is the average of 16 figures, as four judges tested four composites for each experiment.

Sliced apples are often either soaked or steamed before canning. Kohman and Sanborn (1924) showed that it was advisable to soak sliced apples in a weak brine for 16 to 18 hours to remove oxygen from the tissues and thereby to prevent corrosion of the cans. This treatment evidently aids the retention of ascorbic acid, since Eheart (1941) found that applesauce made by a household method from sliced apples soaked for 24 hours in a 2.5-percent salt solution contained about five times as much ascorbic acid as sauce made from apples that were not soaked. Blanching in steam before canning is preferable to soaking in brine, according to Morris and Bryan (1931).

Sauce made from sliced apples that had been soaked 24 hours in 2.5-percent salt solution had a somewhat more yellow and more intense color (higher hue and chroma), and was graded higher by the judges in color and appearance than the standard. The judges preferred, however, the flavor of the standard sauce to that made from soaked apples. Evidently soaking apple slices in brine improved the color, but made the sauce less desirable in taste.

Since apples readily become brown after they are cut, it seemed desirable to study the effect of anti-browning agents on the color and palatability of the sauce. The agents tested were Frulite (thiocarbamide), diluted lemon juice, and diluted pineapple juice.

Use of thiocarbamide or lemon juice improved the color of the sauce as measured by judges' scores for desirability of color and by a lower hue and higher chroma indicating a less yellow, more intense color. Sauce made from fruit treated with thiocarbamide graded as high or higher than the standard in every palatability factor. The flavor of sauce made from untreated fruit was somewhat better than that made from fruit soaked and cooked in water containing pineapple or lemon juice. Use of lemon juice increased the acidity of the sauce, as indicated by a lower pH. The effects on pH of thiocarbamide and pineapple juice were slight.

COOKING METHODS

Data for apples cooked by the standard method, in an uncovered pan, a steamer, and a pressure saucepan are given in full in Table 3. The standard errors of the means, which are shown with each average, varied from ± 0.2 to ± 0.6 for the objective color data and from ± 0.1 to ± 0.3 for the judges' scores. It seems probable that much of the variation was due to differences between the apples used in replicate batches of sauce and to variations in the cooking procedures.

The color of sauce made from apples cooked in an open pan was significantly less intense (lower chroma) and less desirable to the judges than the standard method. The appearance of sauce made in an open pan was also less desirable. These results agree with those of

Pfund (1939) who found that sauces cooked in covered pans were consistently regarded as superior to those cooked in uncovered pans, and with those of Child and Brand (1937) who found that covering during the entire process of cooking improved flavor, color, clearness and tenderness of the apple.

Probably because of the long cooking time that was necessary, sauce made from steamed apples had a weaker, more yellowish color than the standard sauce, as indicated by a higher hue and lower chroma, and received lower scores for all palatability factors. Differences from the standard were highly significant except for texture. Sauce made in the pressure saucepan resembled the standard more closely than did that made by the other two experimental methods. The data obtained should be compared with those for the pressure saucepan in the second metal series.

Because of the profound effect metals have on the color of plant pigments, especially the anthocyanins, it is interesting to compare the effects of using various metal and non-metal utensils in cooking apples (Table 2). These comparisons were made in two series. The second series was done about six weeks after the first; this lapse of time probably accounts for the lower quality of the standard in the second series. The comparison of each variation with its own standard should give accurate results.

In the first metal series, sauce made without contact with metal had a less yellow, more intense color, as indicated by a lower hue and higher chroma, and was preferred by the judges to other sauces in the series. Unfortunately this method cannot be recommended as practical for apples cooked without peeling or coring, because an easy method of straining without metal has not been devised. Forcing the pulp through cotton net was laborious. Sauce for which all the utensils were metal was somewhat yellower (higher hue) and graded in most points very slightly below the standard, for which an enamel pan was used. The addition of soda to the water in which the apples were cooked, made the color of the sauce yellower and less intense, and decreased considerably its palatability. The pH of the sauce was 4.27 compared with 3.67 for the standard, indicating that enough soda was added to cause a definite pH change.

In the second metal series, differences between sauce strained through a cotton net and a metal sieve are similar to those between sauce made without metal and the standard in the first metal series. The particles of apple that went through the enamel colander were coarser than those obtained with the other strainers, making the scores for texture and appearance particularly low. Except in the color of the sauce, the colander seemed to offer no advantages over the wire sieve. The judges'

TABLE 3—Detailed objective color data and judges' scores for sauce made from apples cooked by four methods†

Variation	Objective color‡				Judges' scores†									
	Hue		Chroma		Judge	Desirability of color		Appearance		Texture		Flavor		General acceptability
	1	2	1	2		A & B	C & D	A & B	C & D	A & B	C & D	A & B	C & D	
Standard.....	14.6 13.8 13.6 12.7 14.6 11.8 11.7 12.5	14.1 14.7 14.8 12.1 13.9 10.4 11.1 12.1	6.3 5.9 7.1 6.2 7.5 8.2 8.3 8.4	6.6 5.9 6.6 6.3 6.3 8.6 8.6	1 2 3 4 1 2 3 4	6 7 6 6 6 6 6 6	6 6 6 7 6 6 6 6	6 7 5 6 7 6 5 5	6 6 6 6 6 6 6 6	5 5 4 5 5 5 5 5	6 6 6 6 6 6 6 6	5 5 5 5 5 5 5 5	5 5 5 5 5 5 5 5	5
Average.....	13.0 ± 0.4		7.1 ± 0.2			6.1 ± 0.1		5.9 ± 0.2		5.3 ± 0.2		5.4 ± 0.2		5.1 ± 0.2
Open pan.....	13.9 11.6 11.8 14.2 13.1 10.6 13.0 15.0	14.1 10.9 10.9 12.6 12.6 9.8 13.3 14.5	6.6 7.7 6.2 5.0 6.0 6.9 5.6 6.1	5.5 6.7 7.6 5.2 6.0 6.9 5.4 6.2	1 2 3 4 1 2 3 4	6 6 6 6 5 5 5 5	6 5 5 6 6 4 4 5	6 7 5 5 5 4 4 4	6 6 6 6 6 6 6 6	6 4 4 4 4 5 5 5	6 6 6 6 6 6 6 6	5 5 4 4 5 5 5 4	6 5 4 4 5 5 5 4	6
Average.....	12.8 ± 0.4		6.2** ± 0.2			5.2** ± 0.2		5.1** ± 0.2		5.5 ± 0.2		5.3 ± 0.2		5.0 ± 0.2
Steamer.....	17.4 16.9 10.7 13.1 16.9 15.7 13.9 17.8	18.0 17.7 11.6 13.1 16.5 16.0 14.5 17.7	5.7 4.9 5.4 4.2 4.0 4.2 6.1 4.5	4.9 4.9 5.5 4.8 3.9 4.5 6.0 4.3	1 2 3 4 1 2 3 4	4 5 4 6 3 2 5 5	3 3 2 5 4 4 2 6	4 5 5 6 4 4 2 4	3 4 2 5 — 4 2 5	6 6 6 6 6 6 4 4	6 4 5 5 5 5 5 5	3 5 5 5 5 5 3 3	4 5 5 5 4 4 3 3	4
Average.....	15.5** ± 0.6		4.9** ± 0.2			3.8** ± 0.3		3.9** ± 0.3		5.1 ± 0.2		4.1** ± 0.3		3.6** ± 0.2
Pressure saucepan.....	15.0 14.4 17.5 13.7 13.1 13.1 13.6 14.1	15.0 15.0 16.3 12.6 13.0 12.8 13.5 13.5	4.0 4.6 5.0 6.5 8.4 6.4 5.8	4.2 4.0 6.2 7.3 7.4 6.7 6.9	1 2 3 4 1 2 3 4	6 5 4 6 5 6 6	6 7 6 6 5 6 6	6 4 4 6 5 6 6	6 7 6 6 6 6 6	5 6 4 5 5 7 5	6 7 7 5 6 7 5	5 5 5 5 5 6 5	6 7 6 4 4 6 5	6
Average.....	14.1* ± 0.3		6.0* ± 0.3			5.6* ± 0.2		5.7 ± 0.2		5.8 ± 0.2		5.6 ± 0.3		5.2 ± 0.2

†Each average is given with the standard error of the mean.

‡Objective color was determined for each of eight replicate samples of applesauce by two observers, listed as 1 and 2.

*Two replicate samples of applesauce were mixed for the judges. The four composite samples thus prepared from the eight replicates are listed as A, B, C, and D.

**Difference from corresponding mean of the standard is significant (P = 0.05).

***Difference from corresponding mean of the standard is highly significant (P = 0.01).

preference for the color of the colander sauce is evidently due to its more intense color, as the hues of the wire sieve and colander sauces are close.

The pressure saucepan made sauce that was better than the standard in most respects. The comparison was more favorable than in the series on variations in method, when the pressure saucepan method compared rather closely with the standard. To test the effect of the pan itself, sauce was also made in the pressure saucepan without using pressure, but cooking for the regular 18 minutes. The judges found this sauce less desirable in color, appearance, and texture than sauce cooked under pressure for two minutes.

Apples are not ordinarily undercooked, especially if they are to be put through a sieve, but undoubtedly are often cooked too long. The effect of such variations was examined in the series of experiments on cooking time. Sauce made from fruit cooked five minutes less than the standard length of time was preferred by the judges in all factors except texture. The grade for texture was probably connected with the difficulty experienced in forcing the apples through a sieve. This sauce was yellower (higher hue) than the standard. The judges' scores for desirability of color support the statement of Child and Brand (1937) that color is best preserved in cooking apples by limiting the time of cooking to as short a period as possible. There was not much difference between sauces cooked the standard length of time and five minutes extra, but when cooked for still longer periods, the fruit deteriorated rapidly in quality.

ADDITION OF SUGAR AND ACID

Since fruit packed in sugar sirup often retains its color better during and after canning than water-packed fruit, it seems logical that the addition of sugar to apples before cooking might result in a better-colored sauce than adding the sugar after cooking. This was found to be true, since sauce made from apples cooked with sugar had a somewhat less yellow, more intense color and received higher scores for desirability of color, appearance and texture than the standard, to which sugar was added after cooking (Table 2). Scores for flavor and general acceptability were about the same. This experiment indicates that sauce made from apples cooked with sugar was a little better than that to which sugar was added after cooking. However, the judges in Pfund's (1939) experiments expressed no consistent preferences for sauces in which sugar was added at the end of the cooking process rather than at the beginning or *vice versa*. The addition of sugar at the start of the cooking process has certain disadvantages. It may be wasteful, because when sugar is added to unpeeled, uncored fruit, as in this experiment,

a considerable amount of it is lost in the material remaining in the sieve. Another disadvantage is brought out by Child and Brand (1937) who say that apples are more clear and more easily cooked without scorching if the sugar is added after the fruit has been cooked tender.

As the amount of sugar increased from zero to 10 percent and 20 percent, the hue numbers decreased very slightly, while the judges' scores for desirability of color and appearance improved. The judges graded the unsweetened sauce low in flavor and general acceptability. As Pfund (1939) says, some sugar is necessary to bring out the flavor of apple-sauce. The texture of sauce containing the largest amount of sugar was more desirable, but the judges remarked that it was too sweet. Possibly owing to the good appearance and texture of sauce containing the highest level of sugar, it was scored about the same for general acceptability as the standard.

Since beet sugar appeared to have a very slight effect on the hue, as determined objectively, it seemed advisable to discover whether this effect was due to the sugar itself or to impurities by making sauces with chemically purified sucrose instead of beet sugar. The hues were 14.0, 13.4, 13.2 and the chromas 6.6, 6.2, 6.2, respectively, for 0, 10-percent and 20-percent sucrose. Thus, the use of increasing amounts of chemically purified sucrose resulted in a decrease of hue similar to that with beet sugar. The fruit was evidently a slightly different color, as the hues of sauces containing no sugar were 15.2 and 14.0 in the two series. As usual, comparisons should be made only within each series.

Because of the profound effect of acidity on the color of anthocyanins and flavones, the effects of adding citric, malic and orthophosphoric acids were tested. Since the principal acid in apples is malic (Bigelow and Dunbar, 1917; Nelson, 1927), its addition would simulate conditions in the under-ripe fruit. The addition of the acids reduced the pH of the sauce to 3.27-3.38, as compared with 3.57 for the standard. The color of sauces containing added acid was less yellow and more intense (lower hue, higher chroma) than that of the standard sauce. It will be recalled that the addition of soda in the first metal series made the color of the sauce more yellow and less intense. These color changes would be expected from a knowledge of the behavior of the purified pigments in acid and base, since the addition of alkali causes anthocyanins to become greenish or bluish and changes flavones to a more intensely yellow color. Each of these changes would result in an increased hue number. The judges found the color and appearance of sauces containing acid more pleasing than the standard, but the flavor and general acceptability of the sauces were not improved.

STORAGE OF APPLESAUCE

The hue of sauce stored in a refrigerator did not change much, except to become more yellow on the fifth day. The chroma figures show that the color became less intense on storage of the sauce. The judges scored sauce that had been stored one day higher than the freshly-made sauce, but found that the sauce was less palatable after storage for three or five days.

SUMMARY

Factors influencing the quality of cooked Jonathan apples were studied by investigating the effect on the color and palatability of applesauce of such variables as the condition of the fruit, its preparation for cooking, the cooking method, and the addition of sugar and acid. The color of the products was determined objectively by the Munsell system, hydrogen-ion concentration was found in certain cases, and palatability was graded by judges.

During winter storage of apples, sauces made from them became less desirable, as indicated by a weaker, more yellow color (lower chroma, higher hue) and lower palatability scores. A correlation between the hue and chroma figures in this series showed that when the color of the sauce was yellowish, it was likely to be less intense.

Over-ripe apples made sauce that was less yellow and more intense in color (low hue, high chroma), while sauce from under-ripe fruit was yellower and less intense in color than that from fruit of standard ripeness. Sauce from standard apples was the most palatable.

The judges preferred sauce made from peeled, cored apples to that made from unpeeled cored or uncored apples. In the standard method for the entire experiment, unpeeled, uncored fruit was used. Sauce made from sliced apples that had been soaked in weak brine had a more intense and more desirable color, but graded lower in flavor than the standard. Soaking in thiocarbamide and lemon juice improved the color of the sauce, making it less yellow, more intense, and more desirable to the judges. Sauce made from fruit treated with thiocarbamide compared favorably with the standard in palatability. The judges did not like the flavor of sauce from fruit treated with lemon or pineapple juice.

Apples cooked in a pressure saucepan made sauce that was as good or better than that from apples cooked in a covered pan. Cooking in an open pan and in a steamer were less desirable methods of preparing the apples for sauce. Perhaps owing to the long cooking time necessary, steamed sauce had a weaker, more yellowish color.

Increased contact with metal made the sauce yellower, while apples prepared without the use of metal made sauce having a less yellow,

more intense color. The judges preferred sauce made without contact with metal.

Apples cooked just long enough to make them tender made the best sauce, while those cooked longer periods deteriorated rapidly in quality.

Sauce made from apples cooked in sugar had a less yellow, more intense color, was more attractive, but about the same in flavor and general acceptability as that to which sugar was added after straining. Addition of sugar at the start of the cooking process is wasteful when unpeeled, uncored fruit is used. When twice the usual amount of sugar, either in the form of beet sugar or chemically purified sucrose, was added to strained apples cooked without sugar, the color improved, becoming slightly less yellow.

Addition of citric, malic, or orthophosphoric acid improved the color of the sauce, making it less yellow, more intense, and more desirable, but did not improve the flavor or general acceptability. Addition of soda caused the sauce to have a less intense, more yellow color and to be less palatable.

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